FEEDS AND FEEDING

HENRY AND MORRISON

FEEDS AND FEEDING

A HANDBOOK FOR THE STUDENT AND STOCKMAN

BY

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"The eye of the master fattens his cattle."
—GERMAN ADAGE.

SEVENTEENTH EDITION

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PREFACE

Feeds and Feeding, first published in March, 1898, was received with immediate and widespread favor by practical stockmen, as well as by the professors and students of animal husbandry in our agricultural colleges and secondary schools. The plan of the book had been laid along original lines, and neither time, labor, nor expense was spared in its preparation. In 1910, after nine editions had come from the press, the book was entirely rewritten and improved in many ways. During the lapse of time since that date, the accumulation of new and important matter, both scientific and practical, has made another revision desirable. Accordingly, more than two years ago, the preparation of this, the second revision, was begun, Professor F. B. Morrison, who had so ably assisted with every page of the first revision, becoming joint author herein with the original author.

With a corps of trained assistants he has devoted much time during the past two years to the preparation of this second revision. Previous to and during its writing he has visited numerous stock farms and ranches as well as the agricultural colleges and experiment stations of many states, so that now the combined observations and studies of the joint authors, along the lines of both theoretical and practical animal husbandry, cover quite intimately every state of the Union, as well as parts of Canada and the Old World.

It has been the aim of the authors to give in *Feeds and Feeding* an unbiased and condensed presentation of the most important findings of the investigators of both the Old and New Worlds in the science of animal nutrition, together with the most important results of the vast number of feeding trials which have been conducted at the experiment stations in the United States and other countries, the whole being rounded out by the practical experiences of many of the leading stockmen of America. In a large number of instances, as the text shows, the data and results of important investigations, completed so recently at the experiment stations as not yet to be in print, have been forwarded to the authors by those who were conducting them, in order that the findings might be summarized in this revision.

In Part I the fundamental principles of animal nutrition are first briefly presented, including the most recent discoveries of the biological chemists. The various feeding standards for the different classes of farm animals are then fully discussed, and there is presented a new series of standards—"The Modified Wolff-Lehmann Standards," formulated by the authors,—which are based upon the recent findings of the scientists in this and other countries. To point out some of the economic principles which should be considered in the feeding of live stock, an entirely new chapter—"Economy in Feeding Live Stock"—has been added.

In Part II the many new feeding stuffs are given full consideration along with the old. Especial emphasis is placed upon the importance of combining the legume roughages with corn and the other cereals for the economical feeding of farm animals, and upon the great value of silage for the various classes of live stock. Finally the vital relation of animal husbandry to the economical maintenance of soil fertility, thru the return to the soil of the manurial residue of feeding stuffs, is emphasized.

In Part III there are presented the most important findings obtained by the experiment stations, to date, on the value of the many different feedings stuffs for each class of live stock, and on the effect of various methods of preparing feed, systems of feeding and caring for stock, etc. Rather than simply giving the results of single typical trials on the various subjects, in most cases the data for all the similar trials on a given subject have been carefully compiled and averaged together. The feeder is thus given more trustworthy information in regard to the relative value of the different feeding stuffs.

Feeds and Feeding contains about one-third more matter than the former revision, due not only to the addition of 85 pages, but also to a larger type page, a change of type, and other devices for saving space. This expansion has been made chiefly in Parts II and III, so that teachers, students, and farmers in any section of the country may find in this volume information regarding all the feeds of any importance in that district.

The sincere thanks of the authors are hereby extended to the hundreds of friends who by suggestions and reports of experiments and experiences have furnished invaluable assistance in innumerable ways—only by such help so generously given has the making of this book been possible. Acknowledgment is due Professor E. V. McCollum of the University of Wisconsin for valuable suggestions in the revision of the first six chapters of the book; to Messrs. F. R. Jones, G. Bohstedt, A. J. Dexter, and J. G. Poynton, and Miss Vivian Elver for help in compiling data; and especially to Mrs. Elsie Bullard-Morrison for invaluable assistance thruout the entire work of revision.

W. A. Henry.

Madison, Wisconsin,
October, 1915

PREFACE TO SEVENTEENTH EDITION

The favor with which the second revision of *Feeds and Feeding* was received has exhausted two large editions in less than two years. In this, the seventeenth edition, several changes have been made, the most important of which is the substitution on Page 121 for Armsby's older net energy values the values recently computed by him from the averages given in Appendix Tables II and III of this book.

W. A. Henry.
F. B. Morrison.

Madison, Wisconsin,
July, 1917

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INFORMATION TO THE READER

When seeking information on any subject presented in this book, the reader should first consult the copious index, the figures of which refer to the *page* on which the topic is presented. Additional information bearing on the subject given at other places may be found by following up the numerous references set in black-face figures in parentheses, occurring in the body of the text. These figures refer to the numbered *black-face* side-heads, and *not to the pages.*

INTRODUCTION

LIVE STOCK AND PROFITABLE FARMING

The animals of the farm should be regarded as living factories that are continuously converting their feed into products useful to man. A fact of great economic importance is that a large part of the food they consume is of such character that humans can not directly utilize it themselves. Among the products yielded by the farm animals are not only articles of human diet, such as meat, milk, and eggs, but also such materials as wool, mohair, and hides, which are needed for clothing and other purposes. Another product of greater aggregate money value than any one of these is the work performed by horses and other draft animals. Altogether, the farm animals of the United States yield each year products worth over $5,000,000,000, a sum nearly as great as the value of all the crops annually harvested on our farms.

As the population of our country becomes more dense, most naturally and properly a smaller portion of the crops raised will be fed to animals and a larger part consumed directly by humans. This change must come with the increased demand for human food, since even high-producing animals are able to convert only a part of the feed they eat into food for our consumption. Accordingly, with our increasing population, we should expect the census statistics to show that the number of animals on our farms was failing in some small degree to keep pace with the increase in people. The actual decrease in farm animals compared with population is, however, surprising. While the population of the United States increased 21 per ct. during the decade 1900 to 1910, the number of cattle and sheep decreased, and the number of swine increased but slightly. This indicates that if animal products are to hold their present important place in the diet of our people, American farmers must more thoroly appreciate the basic advantages of stock farming and better understand the principles and methods which are essential to its success.

1. Live-stock farming and soil fertility.—Lured by the high prices which have ruled for grain and other crops in recent years, many farmers all over the country have sold their crops for cash, rather than following the wiser plan of marketing a portion thru the feeding of live stock, and thereby maintaining a balanced agriculture. Seldom have they realized that with every ton of grain thus sold they are removing from their farms $7 to $8 worth of fertility. The loss thru such mining of the soil is gradual, but in a comparatively few years there will result none the less surely worn-out fields, lacking in plant food and humus, which must ever afterwards be fed with fertilizers to secure fair crops. On the other hand, if a part of the crops are fed to live stock and proper care taken of the resulting manure, most of the fertility may be retained on the farm, and the need of commercial fertilizers long delayed. Under intensive stock farming, where more or less milling by-products rich in fertilizing constituents are usually purchased and fed on the farm, the land will even become richer and more productive year by year, with but little need for commercial fertilizers.

When the great South comes into its own, cattle raising will balance cotton raising. Neither the cotton lint nor the oil obtained from the seed, which is a valuable human food, takes an appreciable amount of fertility from the soil. On the other hand, cottonseed meal is the highest in fertilizing value of all common plant products. Fortunately, it is at the same time the highest in feeding value for cattle of all our commonly available feeding stuffs. Therefore, by feeding the meal resulting from his cotton crop to live stock the southern farmer may bring back to his fields most of the fertility drawn out by the cotton plants in their growth. Thus he may reap a double profit.

2. Consumption of feed otherwise wasted.—In exclusive grain farming there is no successful way of utilizing the large amount of roughage, such as straw and corn stover, which results as a by-product in the growing of the cash crops. Such materials are merely in the way and are disposed of in the easiest manner, often by burning, without regard for the loss of vegetable matter, so much needed by the soil. In a well-planned system of stock husbandry all these materials are utilized for feed or bedding. Much forage which can not be consumed by humans and would otherwise be wasted is thus refined thru the agency of animals and converted into a form suitable for the nourishment of man, while a large part of the organic matter is returned to the fields in the resulting manure. Immense amounts of by-products result from the manufacture of the cereals and other seeds into flour, breakfast foods, vegetable oils, etc. While unsuited for humans, some of these by-products are among our most valued feeds for stock. As the density of population increases and the prices of foodstuffs advance, the feed supplied our farm animals must to an ever increasing extent consist of substances resulting secondarily from the making of human food, whether they be coarse roughages or milling by-products.

3. Utilization of land unsuited for tillage.—In some sections of our country much of the land is so rough or stony that it can not be cropped economically. Here cattle will gather the grass on the smoother stretches and sheep will search out the herbage on the more inaccessible, rocky slopes. Over great areas of the West there is too little rainfall to warrant even dry farming, and irrigation will never be possible, either because of lack of water or the roughness of the land. Yet stock will thrive on the scanty but highly nutritious grasses and other forage. Thru well-planned systems of grazing, with additional feed in time of winter storm or parching drought, the western ranges should, at no far distant date.

carry even more stock than they did before large areas were broken up into farms. In the cut-over districts of our country large areas of land may be profitably grazed by live stock before they are finally brought under tillage.

4. Distribution of labor.—Under exclusive grain farming the chief demand for labor is confined to the periods of preparing the land, planting the crops, harvesting, and later marketing the products. During the rush seasons labor is high-priced, and often hard to secure at any cost. On the other hand, live-stock farming offers employment thruout the entire year. Winter, when little other farm work can be done, is the very season when farm animals require the most care and attention, for they are then usually housed instead of at pasture. Because the live-stock farmer can thus offer steady employment he is usually able to secure men who are both more efficient and more reliable than he would otherwise be able to obtain.

5. Intelligent and progressive agriculture.—The whole world over, the most enlightened and progressive agricultural districts are found where live stock provides one of the chief sources of income. This is due to several reasons: The live-stock farmer can not live from hand to mouth, but must providently lay in a store of feed for his animals thruout the winter months. This same care and foresight is then carried into his other activities. Under some systems of agriculture the returns from the year's crops all come in at once, which makes for extravagance and idleness, with resultant poverty until another crop is harvested. On the other hand, under most systems of live-stock farming, income is secured several times during the year.

The care and control of domestic animals, which are intelligent yet submissive to his will, tends to develop the best instincts in man and make him kindly, self-reliant, and trustworthy. The good stockman grows proud of his sleek, well-bred animals and derives a satisfaction therefrom not measured in money. With pride he may hand down to his sons his reputation as a breeder. He is also able to leave them fertile fields which he has built up rather than robbed, a heritage bequeathed by but few grain farmers.

6. Profitable live-stock farming.—In the early days, with land low in price, pasturage abundant, and feed and labor cheap, making a profit from live-stock farming was comparatively easy, even tho one possessed little knowledge of the principles governing the feeding and care of stock. Conditions have now changed. The great western prairies no longer offer rich fields free for the taking, and hence thruout the country fertile land has advanced in price. No less marked has been the increase in the cost of labor and of feeding stuffs. But the price of live-stock products has also advanced, so that satisfactory profits may still be realized from farm animals. However, present conditions call for a more intelligent type of stock farming than has ruled in the past. Good profits are possible only when all the operations are planned intelligently and with good judgment, and there is a thoro appreciation of the requirements of the various classes of animals for food and care.

In the pioneer days of our country the feeds commonly used for live stock were restricted to the grains and forages grown on the farm. Knowledge of the value of these farm-grown products is not now sufficient for intelligent feeding. The problem is complicated by the host of by-products resulting from the manufacture of articles of human food which are offered on the markets as feeding-stuffs for stock. Many of these are valuable and economical supplements to the feeds raised on the farm. However, such products vary considerably in price and even more markedly in nutritive value. Most economical feeding is therefore possible only when the relative value of these different products compared with each other and with the farm-grown crops is clearly understood. In seeking a knowledge of feeds and of feeding we must first consider the plant substances which provide the nourishment for farm animals and study the manner in which these compounds are built up in the living plant. Next we should learn how the food consumed by animals is digested and utilized within the body for the production of meat, milk, work, or wool, and should also study the requirements of each class of animals for food, water, shelter, and exercise. Only then are we in some measure in a position to understand the value and merits for each of the farm animals of the many different feeds, and finally to consider the principles of care and management, the constant observance of which is essential to the highest success in animal husbandry.

FEEDS AND FEEDING

PART I

PLANT GROWTH AND ANIMAL NUTRITION

CHAPTER I

THE PLANT; HOW IT GROWS AND ELABORATES FOOD FOR ANIMALS

I. PLANT GROWTH

Aside from air, water, and salt, plants either directly or indirectly supply all food for animals. It is therefore proper in beginning these studies to consider briefly how plants grow and elaborate this food.

7. The food of plants.—Of the 80 or more elements known to the chemist, only 14 are commonly present in plants, viz.: carbon, hydrogen, oxygen, nitrogen, sulfur, phosphorus, potassium, calcium, magnesium, iron, sodium, silicon, chlorin, and manganese. Iodine also is present in some plants. With the limited exceptions noted further on, plants cannot make use of the elements, as such, for food, but are nourished and supported by water, carbon dioxid (carbonic acid gas), and mineral salts which contain the elements in chemical combination.

Water is the largest single component of plants, that not held in chemical combination constituting from 75 to 90 per ct. of their fresh weight. The plant obtains practically all its water from the soil thru its roots, only a small amount being taken from the air by the leaves. Soil water, absorbed by the roots, enters the cells of which the plant is composed and passes onward and upward thru the stem, moved by capillarity and sap currents, eventually reaching every portion of the structure, being especially abundant in the leaves and growing parts. Thruout its existence the plant takes great quantities of water from the soil, giving most of it off again to the air thru its leaves and other green parts. For every pound of dry matter which plants produce they take from the soil thru their roots from 200 to 500 lbs. of water in humid climates, and as high as 1,800 lbs. in arid regions.

Next to water, carbon dioxid or carbonic acid gas is the great food material of plants. Ten thousand parts of air contain 3 to 4 parts by volume of carbon dioxid, and about 28 tons of this gas rests over each acre of the earth's surface. The supply of carbon dioxid is never exhausted from the air, because thru the decay and dissolution of plant and animal matter it is being constantly returned thereto. On the under surface of plant leaves are innumerable minute openings, or pores, leading inward among the cells of the leaf structure. The air, penetrating these pores, supplies carbon dioxid, which is absorbed into the cells and thus enters the plant proper. In the production of a 15-ton crop of green corn over 5 tons of carbon dioxid are required, to obtain which the plants must take in over 12,000 tons of air.

Nitrogen abounds in the living, growing parts of plants. Despite the fact that about three-fourths of the air is nitrogen gas, with the exception noted farther on plants cannot take it up as such, but obtain their supply from the soil by means of their roots, either in the form of nitrates or as ammonia, chiefly the former.

Plants obtain oxygen, which is a part of all plant compounds, largely from water and carbon dioxid, and not from the free oxygen gas of the air. Some free oxygen is necessary, however, for the growth of green plants.

The mineral substances required by plants are taken from the soil thru the roots. They may be grouped as follows:

Sulfates		potassium
Phosphates		calcium
Nitrates	of	magnesium
Chlorids		iron
Silicates		sodium
Carbonates		ammonium

Sulfur, in small amount, is a component of plant proteins. Phosphorus, likewise in small amount, is present in the life-holding protoplasmic protein of the leaf cells and also abounds in the protein of seeds. Potassium is necessary in the formation of starch and sugar by plants. Magnesium is an essential part of chlorophyll, the green coloring matter of plants, which is necessary for their growth. Calcium is vital to plants, tho its use is not well understood. Sodium, silicon, chlorin, and manganese, tho commonly present, are regarded by some authorities as not essential to plant life.

Free oxygen gas is absorbed by seeds during germination, and a small amount is being constantly absorbed by the leaves and fruits of plants. Bacteria inhabiting nodular growths on the roots of leguminous plants, such as clover, alfalfa, and peas, take nitrogen gas from the air and pass it on in combined form to the host plant, thus indirectly supplying this important element. With these exceptions, the elements, as such, are never used in uncombined form by plants, but serve them only when in chemical combination.

8. Plant building.—Living matter is distinguished from non-living matter by its power to grow, to repair its own waste, and to reproduce itself. In plants the life principle is most in evidence in the transparent, viscous protoplasm found within the plant cells. Because of inherent differences in the protoplasm, each plant possesses an individuality and is able to grow and reproduce itself after its own manner.

The interior of the plant is everywhere bathed with juice or sap, which is the great fluid medium for conveying the chemical compounds, gathered by leaf and root, to the place where they are formed into organized plant substances or building materials proper, and, later, for transporting the materials thus formed to all parts where needed. By means of this sap, the green-colored protoplasm in the leaf cells is supplied with carbon dioxid taken from the air by the leaves, with water, and with nitrates and other soluble mineral salts taken by the roots from the soil.

In some mysterious manner chlorophyll, the sensitive green coloring matter of plants, is able, under the influence of light, to decompose carbon dioxid and water and rearrange their atoms to form primary plant compounds. The excess of oxygen resulting from this union of carbon dioxid and water is given back to the air as a free gas. It is not definitely known whether the first product formed is starch, sugar, or some simpler compound. From the compounds first formed the plant builds up its more complex substances, some of which contain mineral matter taken from the soil as salts. Sugar and starch contain much energy which may be set free as heat when these substances are burned or otherwise broken up. Carbon dioxid and water, on the other hand, have little internal energy, and so on being decomposed do not liberate heat. Energy must therefore be supplied whenever sugar and starch are formed out of the elements contained in these two energy-poor substances. This energy, used by the active life-holding protoplasm in building carbon dioxid and water into energy-holding sugar and starch, comes from the sun, as light.

9. The carbohydrates.—Sugar and starch are the great common elementary structural substances of plants. With the related products, the celluloses and pentosans, they constitute the major portion of all dry plant substance. They are grouped under the term *carbohydrates,* meaning formed of carbon and the elements hydrogen and oxygen in the proportion existing in water, the chemical formula for which is H_2O. The molecular composition of the leading carbohydrates is shown in the following formulae:

Glucose Fruit sugar	$C_6H_{12}O_6$
Cane sugar Malt sugar	$C_{12}H_{22}O_{11}$
Starch Cellulose	$(C_6H_{10}O_5)x$
Pentosan	$(C_5H_8O_4)x$
Pentose	$C_5H_{10}O_5$

Chemists hold that the molecules in the bracketed groups are in reality far more complex than the formulae indicate, the actual molecule being many multiples of the group here given. The formulae not bracketed are held to express the actual atomic composition of the molecule.

All sugars—*cane sugar, glucose, malt sugar, fruit sugar,* etc. — are soluble in the juices of the plant and constitute the common, portable carbohydrate building material of plants, capable, by diffusion and sap currents, of passing to all parts of the structure as needed. Some plants, the beet and the sugar cane for example, store their carbon reserve as sugar. *Starch,* however, is the common intermediate carbohydrate reserve of the plant world. It is insoluble in the juices of the plant and so cannot be directly transported as can the sugars. Starch abounds in most seeds, closely packed about the germs, as in the kernels of wheat, Indian corn, etc. Often it is stored in the underground parts of plants, as in potato tubers. When the starch thus stored is needed in other parts of the plant, it is changed by an enzyme, or ferment, called diastase (**37**), thru the adding on of water, to malt sugar, which is soluble and can be further changed to glucose by the adding on of more water. The sugars so formed can then be passed from cell to cell until their destination is reached, where they may be again changed to starch, pentosans, or cellulose, as required.

Plants are primarily composed of minute cells, variously grouped and modified, the walls of these cells being formed of cellulose, a carbohydrate. *Cellulose* is the great insoluble building substance of the vegetable world, constituting as it does almost the whole of the skeleton or framework of plants. As before shown, cellulose is similar to starch and sugar in general composition and originates from them. In the dense wood of trees the cell walls are thick, in some cases nearly filling the entire cell. In the more tender twigs and leaves they are less dense, while in the still softer portions, such as fruits and seeds, they are thin and delicate. More or less mineral matter or ash is built into the cell walls of plants, being especially abundant in the bark of trees, as is shown by the residue when such material is burned.

The *pentoses* and *pentosans* are carbohydrates with 5 atoms of carbon in the molecule, in place of 6 as in the sugars and starches. The pentoses correspond to sugars, and the pentosans to starches and cellulose. The pentosans, which are usually associated with cellulose in the more woody portions of the plant, form a considerable part of the nitrogen-free extract of roughages and other feeds high in fiber. For example, hay from the grasses and the straw of the cereal grains usually contain over 20 per ct. of pentosans, and wheat bran about 24 per ct., while corn grain contains less than 6 per ct.

10. Vegetable fats and oils.—In some cases the plant stores carbon in the form of *fat,* which is solid at ordinary temperatures, or of *oil,* which is liquid. Such storage is entirely possible since fats and oils are formed from the same elements that exist in the carbohydrates. In vegetable fats and oils the molecules are composed of a larger number of atoms than are those of the sugars, and the proportion of carbon is greater, as the following formulae of 3 common vegetable oils or fats show:

Stearin	$C_{57}H_{110}O_6$
Palmitin	$C_{51}H_{98}O_6$
Olein	$C_{57}H_{104}O_6$

Vegetable oils and fats give off more heat on burning than do the carbohydrates, because they contain relatively more carbon. Oils and fats most abound in the seeds of plants and represent carbon energy stored in condensed form. When seeds containing oil, such as the flax seed, begin to grow, the oil is changed over into products which nourish the growing plantlet the same as is done in ordinary seeds by the sugar which is formed from the stored starch.

11. Nitrogenous compounds.—We have learned how in the life-holding protoplasm of the green parts of plants, especially their leaves, the carbohydrates and fats are formed from the elements of carbon dioxid and water by the energy of the sun. To these life centers, with their green coloring matter, holding sugar and starch, the sap brings nitrates and other mineral salts gathered by the roots from the soil. Thru the union of the elements of the nitrates and other salts with those of the starches and sugars there is formed a new group of complex compounds called *crude proteins,* which, in addition to carbon, hydrogen, and oxygen, found in the carbohydrates, contain nitrogen, sulfur, and sometimes phosphorus. The nitrogenous compounds are the most complex of all plant substances. Osborne of the Connecticut Station gives the following as the probable molecular composition of legumin, a protein found in the seed of the field pea, and hordein, found in the barley grain:

Legumin	$C_{718}H_{1158}O_{238}N_{214}S_2$
Hordein	$C_{675}H_{1014}O_{194}N_{181}S_4$

Because of their great variety and complexity, the nitrogenous compounds are the most difficult of all plant substances for study and classification. For years able organic chemists have been attacking the intricate problems of their structure and composition with great energy and patience. Although their work has greatly advanced our knowledge, yet little more than a beginning has been made in setting forth the differences in the composition of the various nitrogenous or protein compounds, and in pointing out their relative values as nutrients for animals. In discussions of feeding stuffs and the nutrition of animals, the terms *crude protein, protein,* and *amids* are commonly used for designating the various classes of nitrogenous compounds.

Crude protein is the term employed to designate all the nitrogenous compounds of the plant. The chemist finds that about 16 per ct. of the plant proteins is nitrogen. Accordingly, he multiplies the nitrogen found in a given plant substance by 6.25 ($100 \div 16 = 6.25$) and calls the product crude protein. Crude protein embraces 2 great groups of nitrogenous plant compounds, *proteins* and *amids.*

The *amids* may be termed the building stones of the proteins, for from them the plant constructs the more highly organized proteins, and on decomposition the proteins are again broken down into these more simple bodies. These compounds are the portable building compounds of the plant, for they are soluble in its juices and hence may be conveyed wherever needed thruout the plant structure. Commonly included under the general term amids are compounds which the chemist calls *amino acids,* and others which he terms *true amids.* In this work, unless otherwise stated, amids will be used to denote both classes of substances.

Proteins are the more highly organized forms of crude protein. They are not always soluble and therefore in many cases not transportable in the juices of the plant. The proteins form the basis of the living protoplasm of all plants and animals, and so are essential to all life.

The complexity of the proteins is evident from the fact that 18 different amino acids have already been identified, which may enter into their composition. Just as the letters of the alphabet may be combined into innumerable words, so the possibility for the combination of the amino acids into different proteins is almost limitless. Thus far scores of different plant and animal proteins have been separated and examined by the chemists. Some of these, such as egg albumin, contain all the known amino acids, while others, as zein of corn and gliadin of wheat, lack one or more of them. As will be shown later, such incomplete proteins may have a lower value for animal feeding than those which are complete in their composition.

During the period of the plant's life when active growth is taking place, amids are constantly being formed in the living protoplasm out of the nitrates and other mineral salts and the elements composing sugar or starch. These amids are continually being transported to needed points and there changed into the proteins, and as a consequence do not usually accumulate in the plant. Just as starch and sugar may be changed one into the other in the plant, so the proteins and amids may be changed one into the other as plant necessity may require. When germination starts in a seed, an enzyme, or ferment, contained therein acts upon the insoluble proteins stored in and about the germ and changes them to soluble amids, so that the nitrogen may be transported to the newly forming parts of the plantlet. When corn forage is placed in the silo, much of the protein it then contains is changed back to amids thru the fermentations which occur.

Very little crude protein is found in the older woody parts of plants, the greater portion always being concentrated at the point of growth; i.e., in the leaves, seeds, and reproductive parts. The germ of seeds is largely protein, and the rich nutritive substances in the grain close about it usually hold much protein. It is in the life-holding protoplasm in the green parts of plants, principally in their leaves, that all the inorganic compounds taken up by the plant from air and soil are elaborated into true plant substances by sun power. The life processes of the plant are maintained and all changes are wrought thru its nitrogenous or protein compounds, and a knowledge of such fact is not only of interest, but has many practical bearings for the farmer and stockman.

12. Mineral compounds.—The elaboration of food materials in the protoplasmic masses, as well as the development of young plants from the seed, requires the presence of mineral matter, or ash, which is found in small amount everywhere thruout the plant. The leaves contain more ash than do the other parts, due to the life processes within the leaf cells and the constant evaporation of water from their surfaces by which the ash in solution is left behind. The ash content of the bark of trees and stems of plants is also usually high.

13. The end of plant effort.—If we study the life history of a plant, we observe that its first effort is toward self-establishment and enlargement. At this time all the elaborated material, as fast as formed, is transferred to the growing parts that they may be built up and established. As the plant approaches maturity, its energies are changed from growth to reproduction, or the perpetuation of its kind. The nutrients in the juices, which were formerly directed to the growing portions, are now turned toward the reproductive parts. First come the blossoms, then the young enlarging fruits. Into these the sugars, amids, and mineral substances, all elaborated and worked over by the plant in its leaves, are poured in a steady current. The wheat plant resulting from a single kernel bears a hundred fruits in the shape of seed grains, while the Indian corn plant may produce a thousand-fold. In each of these grains is a miniature plant, the germ, composed largely of protein, about which is stored a generous supply of rich nutriment—proteins, starch, sugar, oil, and mineral matter—all in compact, concentrated form, awaiting the time when the germ shall begin life on its own account. In the tuber of the potato the cells are packed with starch, while in the beet root the stored material is largely in the form of cane sugar. Each germ, or reproductive part, is surrounded with food nutrients stored after Nature's choicest plan to aid the new life which is to follow.

14. Plants support animal life.—Nature has decreed that it is the function of plants to build inorganic matter taken from earth and air into organic compounds, by which operation the sun energy employed becomes latent. Thru the life processes the various plant compounds used as food by animals are, after more or less change, built into the animal body, or are broken down within it to give heat and energy. In this change and dissolution the sun energy which became latent or was hidden in the growing plant is again revealed in all the manifestations of animal life. In the coal burning in the grate we observe the reappearance of the energy of the sun which was stored in the plants of ages ago. In the stalks and ears of corn which we feed our cattle we are furnishing energy received from the sun and rendered latent by the corn plant during the previous summer. Thus it is that the stockman, when supplying plants and seeds to the animals under his care, observes in their growing bodies, warmed by internal fires, the energy of the sun transmitted by the plant to the animal. To the plants of the farm the stockman turns for the nourishment and support of his animals. The final step is the consumption of the flesh or milk of the animals by man, whereby sun energy finally becomes human energy. A general knowledge and full realization of how plants live and grow is therefore not only of interest, but also may be helpful in a thousand ways.

II. How the Chemist Groups Plant Substances

In the following table, taken from Appendix Table I, the composition of a few common feeding stuffs is arranged after the manner adopted by agricultural chemists. The first column gives the name of the feeding stuff, followed by others showing the average per cent of the several nutrients which the feed contains. Last is a column giving the number of analyses from which the average composition was computed.

Chemical composition of typical feeding stuffs, from Appendix Table I

Feeding stuff	Inorganic matter		Organic matter				No. of analyses
				Carbohydrates			
	Water	Ash	Crude protein	Fiber	N-free extract	Fat	
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Concentrates							
Dent corn	10.5	1.5	10.1	2.0	70.9	5.0	440
Oats	9.2	3.5	12.4	10.9	59.6	4.4	490
Wheat	10.2	1.9	12.4	2.2	71.2	2.1	858
Wheat bran	10.1	6.3	16.0	9.5	53.7	4.4	7,742
Flax seed	9.2	4.3	22.6	7.1	23.2	33.7	50
Linseed meal, old process	9.1	5.4	33.9	8.4	35.7	7.5	714
Roughages							
Timothy hay	11.6	4.9	6.2	29.9	45.0	2.5	221
Red clover hay	12.9	7.1	12.8	25.5	38.7	3.1	76
Oat straw	11.5	5.4	3.6	36.3	40.8	2.4	41
Kentucky bluegrass, green	68.4	2.8	4.1	8.7	14.8	1.2	32
Corn silage, recent analyses	73.7	1.7	2.1	6.3	15.4	0.8	121
Mangels	90.6	1.0	1.4	0.8	6.1	0.1	38

15. Water.—To determine the amount of water in a fodder the chemist places a small quantity of the material, finely divided, in a dish and ascertains its weight. It is then dried in an oven at a temperature of 212° F. for several hours and again weighed. The difference between the first and last weights represents the amount of water in the sample. Volatile compounds, such as some of the substances which give various plants their characteristic odors, are also driven off by this heating, but the weight of such compounds is generally insignificant. From the second column of the table we learn that even such "dry" feeds as corn, oats, wheat, and wheat bran contain 9 lbs. or more of water per 100 lbs. of the feeding stuff. Timothy and clover hay contain still more water, and such succulent feeds as pasture grass, corn silage, and mangels are largely water.

16. Ash, or mineral matter.—The chemist next burns the sample and ascertains the weight of ash, or mineral matter, which is left. From the third column of the table we learn that 100 lbs. of corn or wheat contains less than 2 lbs. of ash. Oats, with their strawy hulls, and wheat bran, consisting of the outer coats of the wheat grain, carry more ash. The hays and straws are higher in ash than such grains as corn or wheat, due to the accumulation of mineral matter in the leaves during growth, to earthy matter washed upon the growing plants by rain, and to dust settling on the roughage before it is housed. Such foreign material is not really plant ash, but of necessity is reported as such. Owing to their high water content, the ash in 100 lbs. of fresh grass, silage, and mangels is low. The ash and water of plants together constitute the so-called *inorganic matter;* the other components—crude protein, carbohydrates, and fat—are termed the *organic matter.*

17. Crude protein.—The process of determining the nitrogenous constituents of feeding stuffs is too complicated for presentation here. Suffice it to say that the nitrogen content is found, and the result multiplied by 6.25 to give the crude protein, since about 16 per ct. of plant protein is nitrogen ($100 \div 16 = 6.25$). From the table we learn that 100 lbs. of wheat bran contains 16.0 lbs. of crude protein, while the amount in wheat is 12.4 lbs. and in dent corn only 10.1 lbs. per 100 lbs. Red clover hay contains over twice as much crude protein as timothy hay.

18. Fiber.—The woody portion of a feeding stuff is determined by boiling a sample thereof successively in weak acid and alkali and washing out the dissolved matter. That which remains is termed *fiber.* As is shown later (**48**), fiber, which consists mostly of cellulose, is less digestible and hence has a lower nutritive value than the other nutrients of feeding stuffs. Corn contains but 2.0 and wheat only 2.2 per ct. of fiber, while, owing to the woody hulls, oats contain 10.9 per ct. Most roughages, especially the straws, are much higher in fiber than the concentrates. Mangels contain but 0.8 per ct. fiber; were they dried to the same water content as oats they would contain only 7.7 per ct. fiber—less than oats.

19. Fat.—A sample of the pulverized dried fodder is treated with ether, which dissolves the fats, waxes, resins, chlorophyll, or green coloring matter, and similar substances. This, called *ether extract* in works on plant analysis, is for convenience termed *fat* in this work. The ether extract of seeds is nearly all true fat, or oil, while that of the leaves and stems of plants contains much chlorophyll, wax, etc. Corn and oats carry more fat than the other cereals. Some seeds, such as flax seed, are so rich in oil that it may be extracted from them by crushing and subsequent pressure.

20. Nitrogen-free extract.—The *nitrogen-free extract,* expressed in the tables in this book as *N-free extract,* embraces the substances that are extracted from the dry matter of plants by treatment with weak acids and alkalies under standard conditions, less the crude protein, fat, and ash. It is determined by difference and not by direct analysis. The total dry matter in a feeding stuff minus the sum of the ash, crude protein, fiber, and fat, equals the nitrogen-free extract. It embraces the sugars, starches, pentoses, non-nitrogenous organic acids, etc., of the plant. The nitrogen-free extract is more soluble and hence more digestible than the fiber, and thus has a higher nutritive value. (48) Over 70 per ct. of both corn and wheat is nitrogen-free extract, largely starch. The roughages, carrying much woody fiber, contain less of these more soluble carbohydrates than the concentrates.

21. Carbohydrates.—The nitrogen-free extract and fiber together constitute the *carbohydrates.*

By the present method all plant substances are grouped under the terms crude protein, fiber, nitrogen-free extract, and fat, without regard to the differences in composition and feeding value of the different individual proteins, carbohydrates, and fats which make up these classes. In many particulars this is unsatisfactory. In time chemists will work out a more accurate, tho necessarily more complicated, classification, but at present for the great majority of feeds there is nothing better than what is here given.

22. Roughages and concentrates.—In discussing feeding stuffs it is desirable to differentiate between those which are of coarse, bulky nature and others which are more condensed and more nutritious. Accordingly, the terms "concentrate" and "roughage" employed in the first edition of this book are retained, since they are now widely recognized and used.

Concentrates are feeding stuffs of condensed nature, which are low in fiber and hence furnish a large amount of digestible matter. Examples of this class of feeds are the various grains, as Indian corn, wheat, and oats, and milling by-products of high feeding value, as wheat bran, linseed meal, gluten feed, etc.

Roughages are the coarser feeding stuffs, which are high in fiber and supply a lower percentage of digestible matter. Such feeds as hay, corn fodder, straw, and silage belong to this class. Some of the low-grade milling by-products, such as oat hulls, ground corncobs, and peanut hulls are roughages, rather than concentrates, for they are largely fiber and furnish but little nutriment. Roots are watery and bulky, and contain relatively little nutriment per pound, yet based on the composition of the dry substance they are more like concentrates than roughages, as they are low in fiber. They are really watery, or diluted, concentrates, tho for convenience they are included under fresh green roughages in Appendix Table I.

III. The Study of an Acre of Corn

The great basic facts in plant life, briefly set forth in the preceding pages, are admirably illustrated by a study of Indian corn, the greatest of our agricultural plants, such as has been made by Ladd at the New York (Geneva) Station[1] and Jones at the Indiana Station[2].

23. Changes in a growing corn crop.—Analyzing the plants at various stages from July 24, when they were about 4 feet high, until Oct. 8, when the kernels were hard, Jones secured the following data, based on an average stand of 10,000 stalks per acre:

Composition of an acre of Indian corn at different stages

Stage of growth	Total wt. of green crop	Dry matter in crop	Ash	Crude protein	Fiber	N-free extract	Fat
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Four feet high, July 24	5,138	731	90	149	170	282	40
First tassels, Aug. 6	18,827	2,245	195	360	670	977	42
Silks drying, Aug. 28							
Corn and cob	4,839	755	24	102	147	473	9
Stalk, blade, etc	19,488	3,812	248	334	1,056	2,133	40
Total	24,327	4,567	272	436	1,203	2,606	49
Milk stage, Sept. 10							
Corn and cob	7,288	2,268	50	252	263	1,648	55
Stalk, blade, etc	19,422	3,906	278	292	1,098	2,198	40
Total	26,710	6,174	328	544	1,361	3,846	95
Glazing stage, Sept. 24							
Corn and cob	8,620	3,866	66	346	312	2,985	158
Stalk, blade, etc	17,130	4,238	323	220	1,211	2,440	44
Total	25,750	8,104	389	566	1,523	5,425	202
Silage stage, Oct. 1							
Corn and cob	9,292	4,625	72	450	324	3,600	179
Stalk, blade, etc	15,983	4,304	297	210	1,278	2,484	36
Total	25,275	8,929	369	660	1,602	6,084	215
Ready to shock, Oct. 8							
Corn and cob	9,259	5,186	76	492	368	4,027	223
Stalk, blade, etc	12,994	4,226	307	199	1,369	2,309	42
Total	22,253	9,412	383	691	1,737	6,336	265

From July 24, at a stage when sometimes fed as soilage, to Aug. 28, when the silks were drying, the crop increased over 19,000 lbs. in total weight and nearly 4,000 lbs. in dry matter. The increase in total weight was thereafter less rapid, reaching the maximum when the kernels were in the milk stage. After this the gross weight decreased by over 4,000 lbs., due to drying out as it matured. The dry matter, however, continued to increase rapidly until the plants were fully ripe. Indeed in less than a month following Aug. 28 the acre of corn stored over 3,000 lbs. of dry matter! When four feet high the crop was nearly 86 per ct. water

[1] N. Y. (Geneva) Rpt. 1889. [2] Ind. Bul. 175.

and only about 14 per ct. dry matter; while when the kernels were hard and the husks dry over 42 per ct. was dry matter. On Aug. 28 less than 17 per ct. of the total dry matter was in the ears; by Oct. 8 the ears contained over half the dry matter in the total crop.

24. Ash or mineral matter.—The total ash increased rapidly until the plant reached its full height. During the period of greatest starch formation, Aug. 28 to Oct. 1, the increase in potash was especially rapid.

25. Crude protein.—The most rapid increase in crude protein, the nitrogenous portion, occurred before the plants were tasseled, when cell growth was more active. After the ears were silked, as is shown in the following table from Ladd, the amids—the soluble circulating nitrogenous compounds—did not increase.

Changes in crude protein in growing corn crop

Stage of growth	Amids Lbs.	Protein Lbs.
Tasseled	69	171
Silked	158	279
Kernels in milk	102	377
Kernels glazed	152	491
Ripe	109	569

Altho amids—the building-stones of the proteins—were constantly being formed during the development of the plants, they were in turn quickly built over into the more complex, stable proteins. Thus, there was a steady and marked storage of proteins up to maturity. At all stages of growth nearly all the amids are in the stalks and leaves, the amids in the ears never exceeding 1.5 lbs. per acre, according to Jones. At maturity, Oct. 8, over 71 per ct. of all the protein in the crop was stored in the ears, principally in and about the germs of the kernels, ready to carry on the vital functions whenever the grains might find lodgment in the soil and begin growth to form new corn plants.

26. Fiber.—The stalk of corn must be strong and sturdy to carry the abundant foliage and especially the heavy ear—hence the increase in fiber, the woody framework of the plant, which was especially rapid till the skeleton of the plant was grown.

27. Nitrogen-free extract.—The nitrogen-free extract, the most valuable portion of the carbohydrates, made up of sugars, starch, and the other more soluble carbohydrates, increased more than 2.5 tons between tasseling and ripening. As is shown in the following, Ladd found that after the milk stage there was practically no increase of either glucose or sucrose, but a large storage of starch.

Changes in glucose, sucrose, and starch of growing corn crop

Stage of growth	Glucose Lbs.	Sucrose Lbs.	Starch Lbs.
Tasseled	58	9	122
Silked	300	111	491
In milk	665	129	707
Glazed	720	95	1,735
Ripe	538	149	2,853

The table shows that, altho sugars were being steadily formed in the leaves of the plant from tasseling to ripening, they were continuously being transferred to other parts, especially the swelling kernels of the ear. Here a large portion was changed to insoluble starch and compactly stored about the germs to serve as food for the future plantlets. Another portion of the sugars was changed into cellulose to form the woody framework of the plant structure. The elements of a third portion were combined with nitrates and other mineral matter from the soil to form the nitrogenous amids and proteins. It was because of such continuous transference and change that the sugars showed no material increase.

Up to the milk stage starch formed only a small part of the total nitrogen-free extract; after this it increased rapidly until by maturity nearly a ton and a half of starch had been formed. Ladd found that the other soluble carbohydrates, which increased up to the glazing stage, consisted chiefly of pentoses and the more soluble pentosans and celluloses. A study of the several tables shows most plainly the heavy losses of valuable nutrients which are sure to occur when a crop of Indian corn is harvested before it has fully ripened.

In producing this acre of corn, probably not over 10 lbs. of seed was placed in the ground in the spring time. From this insignificant beginning, by the following October, about 130 days later, the resultant plants had gathered inorganic matter—carbon dioxid from the air, and water, nitrogen, and mineral matter from the soil—and built all these, first into primary organic forms, and finally into complex organic parts of their structure. The product of such building amounted to over 11 tons of green or 4.7 tons of dry matter, all largely available for nourishing the animals of the farm and, thru them, man. This is a forceful illustration of Nature's wonderful processes of food production occurring all about us under the guiding mind of man.

The reader who will thoroly familiarize himself with this study of the growing corn plant can readily extend his acquirement to all the other crops of the farm. Thus equipped he is in position to study the composition of the bodies of farm animals and consider how they are built up and maintained by food derived from plants, as later presented.

CHAPTER II

COMPOSITION OF THE ANIMAL BODY—DIGESTION—METABOLISM

I. Composition of the Animal Body

Division III of the preceding chapter sets forth the yield and composition of an acre of Indian corn, thereby showing how the several nutrients of feeding stuffs are elaborated by the plants of the farm. We will next consider the nature and composition of the bodies of farm animals, which are built up and nourished by plants.

28. The animal body.—The unit of the animal body is the protoplasmic life-holding cell, which, associated with myriads of others and modified in innumerable ways, makes up the body structure. Both the cell envelop and its contents are of nitrogenous material in most complex combination.

In studying the higher animals we may regard their bodies as consisting of a bony skeleton of mineral character surrounded by an elaborate muscular system. Fatty tissue permeates the bones and muscles, filling in and rounding out the body form, and around all is the enveloping skin. Within the body cavity are the various special organs, such as the heart, stomach, etc., designed for dissolving, assorting, distributing, and utilizing the nutritive matters of the food and for conveying and disposing of the waste. All these organs are nitrogenous or protein in nature, as are also a part of the organic matter of the bones and a large portion of the nerves, which control and direct all body activities. We have seen that in plants the great structural material is cellulose, a carbohydrate, and that the common stored reserve material is starch, also a carbohydrate. In the animal body, however, while the glucose in the blood and tissues and the glycogen in the liver and other organs perform important functions, these carbohydrates at no time form an appreciable part of the animal's weight. (60)

29. Composition of animal bodies.—To aid in a study of the composition of the bodies of farm animals we have the following invaluable data gathered by Lawes and Gilbert[1] of the Rothamsted (England) Experiment Station, whose classic investigations stand as models in agricultural research. The first division of the table shows the composition of the entire body (fasted weight) of the several animals, and the second part the composition of their carcasses. Store animals are those in thrifty condition, but not fat.

[1] Jour. Roy. Agr. Soc. Eng., 1898; U. S. Dept. Agr., Office Expt. Sta., Bul. 22.

Due to the fact that the gains during fattening are chiefly fat (**122**), the animals of each kind contain a higher percentage of protein and a much lower percentage of fat before being fattened. Thus while 14.8 per ct. of the body of the store sheep is protein and 18.7 per ct. fat, the extra-fat sheep contains 45.8 per ct. fat and only 10.9 per ct. protein. The third column shows that in general the percentage of mineral matter, or ash, decreases as the animal fattens, because fatty tissue is low in ash. Due to the relatively light skeleton, the body of the pig in store condition contains but 2.67 per ct. ash and only 1.65 per ct. when fat, the lowest of any of the farm animals.

Composition of the entire bodies and carcasses of farm animals

Description of animal	Protein	Fat	Mineral matter (ash)	Total dry substance	Water	Contents of stomach and intestines in moist state
Division I. Per cent in the entire animal (fasted live weight)						
Fat calf	15.2	14.8	3.80	33.8	63.0	3.17
Half-fat ox	16.6	19.1	4.66	40.3	51.5	8.19
Fat ox	14.5	30.1	3.92	48.5	45.5	5.98
Fat lamb	12.3	28.5	2.94	43.7	47.8	8.54
Store sheep	14.8	18.7	3.16	36.7	57.3	6.00
Half-fat old sheep	14.0	23.5	3.17	40.7	50.2	9.05
Fat sheep	12.2	35.6	2.81	50.6	43.4	6.02
Extra-fat sheep	10.9	45.8	2.90	59.6	35.2	5.18
Store pig	13.7	23.3	2.67	39.7	55.1	5.22
Fat pig	10.9	42.2	1.65	54.7	41.3	3.97
Average of all	13.5	28.2	3.17	44.9	49.0	6.13
Division II. Per cent in carcass						
Fat calf	16.6	16.6	4.48	37.7	62.3	....
Half-fat ox	17.8	22.6	5.56	46.0	54.0	....
Fat ox	15.0	34.8	4.56	54.4	45.6	....
Fat lamb	10.9	36.9	3.63	51.4	48.6	....
Store sheep	14.5	23.8	4.36	42.7	57.3	....
Half-fat old sheep	14.9	31.3	4.13	50.3	49.7	....
Fat sheep	11.5	45.4	3.45	60.3	39.7	....
Extra-fat sheep	9.1	55.1	2.77	67.0	33.0	....
Store pig	14.0	28.1	2.57	44.7	55.3	....
Fat pig	10.5	49.5	1.40	61.4	38.6	....
Average of all	13.5	34.4	3.69	51.6	48.4	....

The fourth and fifth columns, giving the percentages of total dry substance and water, show that in all but the extra-fat sheep and the fat pig, water is the largest single constituent of the body. For all the animals studied, on the average 49 lbs. in every 100 of the body weight, or nearly half, is water. This brings out strikingly the great importance of water in the animal body. The percentage of water both in the entire body (Division I of table) and in the carcass (Division II) is higher in the fat calf than in the fat ox, and also higher in the fat lamb than in the fat sheep. All animals contain a higher percentage of water when lean than when fattened.

30. Nitrogen and ash.—The following table shows the nitrogen and the principal ash constituents in the fasted live weight of the animals analyzed at Rothamsted, and also in milk and unwashed wool:

Ash and nitrogen in 1000 lbs. of farm animals, milk, and unwashed wool

	Nitrogen (N)	Phosphoric acid (P_2O_5)	Potash (K_2O)	Lime (CaO)	Magnesia (MgO)
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Fat calf	24.64	15.35	2.06	16.46	0.79
Half-fat ox	27.45	18.39	2.05	21.11	0.85
Fat ox	23.26	15.51	1.76	17.92	0.61
Fat lamb	19.71	11.26	1.66	12.81	0.52
Store sheep	23.77	11.88	1.74	13.21	0.56
Fat sheep	19.76	10.40	1.48	11.84	0.48
Store pig	22.08	10.66	1.96	10.79	0.53
Fat pig	17.65	6.54	1.38	6.36	0.32
Milk	5.76	2.00	1.70	1.70	0.20
Unwashed wool	54.00	0.70	56.20	1.80	0.40

The table shows that the nitrogen in each 1000 lbs. (fasted live weight) of the bodies of farm animals varies from about 17 to 27 lbs., being least in the fat pig and greatest in the half-fat ox. Lime, the largest mineral constituent of the bones, ranges from about 6 lbs. per 1000 lbs. of carcass in the fat pig to over 21 lbs. in the ox. Phosphoric acid almost equals lime in quantity, while potash runs only from 1 to 2 lbs. per 1000 lbs. of animal, and magnesia still less. Soda, silica, iron, etc., are found in small quantities.

31. Plants and animals compared.—One of the fundamental differences between plants and animals is that in plants the walls of the cells of which they are composed are of carbohydrate material, while in animals the walls of the body cells are of protein substances. Thus plants are on a carbon and animals on a nitrogen foundation. The higher plants are nourished by inorganic matter, while animals live upon both organic and inorganic substances, principally the former. Plants absorb thru their leaves great quantities of carbonic acid gas, composed of carbon and oxygen, retaining the carbon and giving off the oxygen as waste. Animals take free oxygen thru their lungs and combine it with carbon to form carbonic acid gas, which is thrown off as waste in the breath. Thus the two great classes of living objects are interdependent.

In the animal body the organic material derived from plants may be built into still other highly organized compounds, usually protein in character. Thus built, matter has reached its last high stage of organized existence, and its fall or descent soon occurs. In the daily waste of the body or upon the withdrawal of life, this highly endowed organic matter is broken down into inorganic compounds, to begin again the eternal round of Nature.

II. Digestion

32. Digestion.—The changes which food undergoes within the digestive tract of the animal to prepare it for absorption and ultimate use in building new tissues, repairing body waste, and as a source of energy are collectively known as *digestion.* Digestion is effected by enzymes, or ferments, elaborated by glands of the mouth, stomach, pancreas, and small intestines, and by the bile, secreted in the liver. Bacteria inhabiting certain parts of the digestive tract attack the woody cellulose of the food, breaking it down and thereby freeing nutrients. In addition to the action of the secretions and bacteria, the food in its course thru the digestive tract is subjected to mechanical processes which tend to reduce it to a fine state of division, the object of the whole process being to separate from the useless matter those constituents which are to nourish the body.

33. Nutrients.—The term *nutrient* is applied to any food constituent, or group of food constituents, of the same general chemical composition, that may aid in the support of animal life. Crude protein, the carbohydrates, and fat constitute the generally recognized primary classes of nutrients, altho air, water, and mineral matter might likewise be so termed.

The term *digestible nutrient* covers that portion of each nutrient which is digested and taken into the body, as determined by digestion trials with various mature animals. (66)

34. Concerning rations.—On the farm a *ration* is the feed allowed or set apart to maintain a given animal during a day of 24 hours, whether all thereof is administered or fed at one time or in portions at different times.

A *balanced ration* is the feed or combination of feeds furnishing the several nutrients—crude protein, carbohydrates, and fat—in such proportion and amount as will properly and without excess of any nutrient nourish a given animal for 24 hours.

A *maintenance ration* is one that furnishes enough, but no more, of each and all of the several nutrients than is required to maintain a given resting animal, so that it will neither gain nor lose in weight.

35. The alimentary tract.—The digestive tract is a long, tortuous tube passing thru the animal from mouth to vent, enlarged in places for the storage of food or waste. Within its linings are secretory organs furnishing various fluids of digestion, and into it, from other specific secretory organs located near by, pour still other digestive fluids. Within its walls are nerves controlling its action, arteries which nourish it with fresh blood, and veins and lymphatics which absorb and carry from its interior the products of digestion, as well as water, mineral matter, and gases. It should be borne in mind that the contents of the stomach and intestines are really outside the body proper. Only when a substance has passed into or thru the walls of the digestive tract has it actually entered the body of the animal.

Ruminants (animals which chew the cud), including the ox, sheep, and goat, have much more complicated digestive tracts than other animals. In the horse and pig the gullet is a simple muscular tube passing from the mouth to the stomach. On the other hand, in ruminants the gullet is expanded just before the true stomach, or abomasum, is reached into 3 compartments of great aggregate capacity, the first of which is the paunch, or rumen; the second, the honeycomb, or reticulum; and the third, the manyplies, or omasum. Of the 4 stomachs the paunch is by far the largest.

The length and capacity of the intestines and the capacity of the stomachs of different mature farm animals are shown in the following table. Obviously these values will vary widely, depending on the size of the animal.

Capacity of stomach and capacity and length of intestines of farm animals

Animal	Capacity of stomach and intestines	Average length of intestines
	Quarts	Feet
Horse		
Stomach*	19.0	....
Small intestine	67.4	73.6
Large intestine	137.4	24.5
Total	223.8	98.1
Sheep		
Rumen	24.7	....
Reticulum	2.1	....
Manyplies	1.0	....
Abomasum	3.5	....
All 4 stomachs	31.3	....
Small intestine	9.5	85.9
Large intestine	5.9	21.4
Total	46.7	107.3
Ox		
All 4 stomachs	266.9	....
Small intestine	69.7	150.9
Large intestine	40.1	36.3
Total	376.7	187.2
Hog		
Stomach	8.5	....
Small intestine	9.7	60.0
Large intestine	10.8	17.1
Total	29.0	77.1

* Chauveau, Comparative Anatomy of the Domestic Animals, places the capacity at 3 to 3.5 gallons.

While the stomach of the horse holds only 19.0 qts., the 4 stomachs of the ox have a capacity of 266 qts., or 14 times as much. On the other hand, the large caecum, or blind gut, of the horse, a part of the large intestine, gives the large intestine a capacity of 137.4 qts., compared with 40.1 qts. for the ox.

In young ruminants the first 3 stomachs are less developed than in mature animals. Colin found that the first stomach, or the paunch, of a calf held 2.6 lbs. of water; the honeycomb 0.22 lb.; the omasum 0.35 lb.; and the true stomach 7.7 lbs. As the diet of the growing calf changes to more solid food, such as grass, hay, and grains, the rumen, or paunch, gradually increases in size, until in the grown ox it holds 4 times as much as the other 3 stomachs combined.

The alimentary tract of the sheep is similar in structure to that of the ox. The hog has neither the 4 stomachs of the ruminant nor the large caecum of the horse, and is hence not fitted to consume large amounts of roughage.

36. Mastication.—In the mouth of the animal food is crushed and ground by the teeth and at the same time is moistened by the alkaline, somewhat slimy saliva, moist and slippery masses being formed which pass readily thru the gullet into the stomach. Mingling saliva with the food during mastication, or chewing, aids the sense of taste by dissolving small amounts of food which affect the nerve ends of the tongue. Colin[2] found that a horse fed on hay secreted 11 to 13 lbs. of saliva per hour. Oats require a little more than their own weight, green fodders half, and dry fodders 4 times their weight of saliva during mastication. If the ration for a horse amounts to 11 lbs. of hay and 11 lbs. of other dry fodder, this will require 4 times its weight of saliva, or 88 lbs., to which must be added 4.4 lbs. secreted during rest, making 92.4 lbs. in all.

Ruminants while eating chew their food only enough to moisten it, if dry, and form it into masses of suitable size to be swallowed. When hunger is satisfied they seek a quiet place, if possible, and proceed to return the food in "cuds" to the mouth, chewing each thoroly before reswallowing. The gullet of ruminants opens into the first 3 stomachs thru a slit (called the esophageal groove), which has an exceedingly important function in the process of rumination. When the ox swallows the masses of solid food, which are so large as to distend the gullet, on coming to the slit they are pressed out, just as would be the case if one tried to force thru a rubber tube with a slit an object which fitted it tightly. These masses of food are usually pushed into the paunch until it is full, and then into the honeycomb instead.

When the animal ruminates, or "chews the cud," the food is forced back to the mouth in masses, or "cuds," thru the same slit by contractions of the muscular paunch, the honeycomb, and of the gullet itself. The ox chews each cud of about 4 ounces for a little less than a minute, adding saliva until the finely divided material becomes more or less souplike. On being reswallowed, this finely divided material usually flows along the gullet past the slit, and directly into the third stomach, from which it passes into the fourth or true stomach. Water or liquid food may not be forced thru the slit into the paunch but may pass at once to the third stomach.

Animals do not ruminate during sleep, while working, when excited, or if in pain. The fact that the ox requires 7 to 8 hours daily for rumination handicaps him somewhat as a work animal, for if his hours of work are long he must dispense with sleep to masticate his food.

[2] Smith, Physiol. Dom. Anim., p. 286.

37. The saliva.—In addition to preparing the food for swallowing, with most animals the saliva performs a highly important digestive function thru the enzyme, called ptyalin, which it contains.

Enzymes are mysterious organic compounds which are able to change or break down other organic compounds without themselves being broken down.

38. Ptyalin.—The first enzyme of digestion, *ptyalin,* converts the insoluble starches of food into malt sugar. The proteins and fats of food are not changed by the action of the saliva.

Since most of the changes which food substances undergo during digestion are effected thru enzymes, their general nature should be understood by the student, and ptyalin action serves as an example. If a quantity of starch is treated with saliva and the whole kept at body temperature, the starch so treated will gradually dissolve, and after a time malt sugar will be found in its stead. The complex starch molecule has been cleaved or split into simpler ones by the action of the ptyalin. The enzyme causing this change is itself not altered in character or function, however, or seemingly exhausted in energy thereby, but is still capable of changing more starch into sugar. So far as known, there is no limit to the amount of sugar which a given quantity of ptyalin will produce if the supply of starch is maintained and the resultant sugar is continuously removed from the solution. If the saliva is heated above 176° F., it will no longer possess this power. At the temperature of ice water its action ceases, altho the enzyme is not destroyed, for on warming it becomes active again. Acids destroy ptyalin if added much beyond the point of neutrality. Each of the several enzymes of digestion is capable of acting on only one of the groups of nutritive substances—on either proteins, carbohydrates, or fats. Some act only in the presence of acids, and others only in neutral or faintly alkaline solutions. Recent investigations[3] show that the saliva of some animals contains little or no ptyalin. The saliva of man, monkeys, rabbits, rats, and mice has the greatest starch digesting power and that of swine contains a fair amount of ptyalin, while the saliva of horses contains but a small quantity and that of dogs and oxen little or none.

39. Digestion in the simple stomach.—With such animals as the horse and pig, which have simple stomachs, the food passes directly from the mouth, where it remains but a comparatively short time, thru the gullet to the single stomach. There it is acted on by the gastric juice, which consists of water containing the enzymes, pepsin and rennin, and from 0.2 to 0.5 per ct. of hydrochloric acid.

Pepsin, which acts only in weak acid solutions, converts the very complex proteins into soluble and simpler, tho still complex, products known as proteoses and peptones. *Proteoses* and *peptones* are soluble nitrogenous compounds, simpler than the proteins from which they originate. They are the result of the partial cleavage of proteins with the addition of water.

[3]Oppenheimer, Handb. der Biochem., 1910, III, Part II, p. 38.

Rennin is the enzyme which curdles milk. The membranous lining of the stomachs of calves yields the rennet of commerce, which contains this enzyme. One part of rennin will coagulate 400,000 parts of milk. This enzyme is an interesting provision of nature for changing milk into a solid form so the animal may get the full value from it. Altho liquid, milk is not in condition to be taken directly into the animal system, but, like solid foods, must first undergo digestion. Milk being liquid, the stomach would naturally pass it quickly on to the small intestine, but if this occurred it would not be sufficiently acted on by the pepsin. Rennin quickly converts the milk into a solid curd which is easily retained by the stomach until dissolved by the action of the digestive juice.

Acid destroys the power of ptyalin to convert starch into sugar. The construction of the stomach, however, is such that the action of ptyalin on the food after it reaches that organ, following mastication, is not too promptly checked. The first portion of the stomach, into which the gullet directly leads, secretes pepsin but no acid. The action of ptyalin on the starches of the foods continues, therefore, in this part of the stomach. The intestinal or rear end of the stomach, on the other hand, secretes little pepsin but much hydrochloric acid. Here the conversion of the starches into malt sugar by the ptyalin ceases, and pepsin digestion becomes active. Only the preliminary steps of digestion are accomplished in the stomach, and relatively little absorption of the digested nutrients takes place from it. Sugars may be absorbed to some extent, but the proteoses and peptones produced from the breaking up of protein, and also the fats, are mostly carried into the small intestine along with the other matter.

Soon after the food reaches the stomach that organ begins a series of orderly movements for the delivery of its contents into the small intestine. In this delivery the stomach contracts at the middle region, and the wave of contraction proceeds slowly and regularly toward the intestinal end, one wave following another. When digestion has progressed to some extent, every time the contraction reaches the rear end of the stomach, the ring of muscles which keeps the stomach shut off from the small intestine relaxes and allows a small quantity of the semi-liquid contents of the stomach to spurt thru into the intestine. After this the ring of muscles again contracts, thereby closing the entrance. The stomach in turn slowly relaxes, and after a certain length of time, varying in different animals, the process is repeated. By this means the fluid portions of the contents of the stomach are squeezed out and carried into the small intestine, while the more solid portions remain behind for further action by the gastric juice. In animals with a simple stomach little or no churning or mixing of the food is produced by the movements of the stomach. The contents are simply pushed gradually toward the intestinal end of the stomach by the waves of muscular contraction.

40. Digestion of ruminants.—The first 3 stomachs of ruminants are important organs of digestion, although they secrete no enzymes, but only water. The nutritive substances within the cells of plants are enclosed within the cellulose cell walls. Where the cell walls are formed of hard, thickened cellulose, the nutritive substances within are not readily reached and attacked by the fluids of digestion. As stated before, when solid food is first swallowed it passes chiefly into the paunch. Here it is softened by the moisture, slowly but thoroly mixed by muscular contractions, and even macerated by being ground against the rough lining.

In the first stomachs, especially in the paunch, the fermentation of cellulose by bacteria takes place, the walls of the cells being thereby more or less broken down and their contents set free, thus becoming available for digestion. In this fermentation gases are given off, which are ordinarily absorbed into the blood and carried away. When fresh, easily fermented forage, such as green clover or alfalfa, is eaten, gases may be evolved so rapidly that the blood circulation cannot take them up as fast as formed, and "hoven," or "bloat," results. No enzymes of the digestive tract are able to digest the pentosans, which are present in considerable amount in roughages and other feeds high in fiber. (**9**) Like cellulose, however, these compounds are digested by the bacteria in the paunch and thus serve as nutrients. Not only are the fiber and pentosans broken down, but when the food contains sugars these also are sometimes attacked by bacteria in the paunch, which action is detrimental, for in such cleavage, or breaking down, a considerable percentage of their energy is lost as heat and gas. (**84**) The fact that only a small amount of ptyalin is present in the saliva of the ox and sheep, or that it is entirely absent, as is claimed by some, is thus advantageous. If their saliva easily converted starch into sugar, a large amount of sugar would be formed in the paunch, which would then in turn be attacked by bacteria, with much resultant loss of nutriment. Besides the digestion in the paunch caused by bacteria, more or less is also undoubtedly effected by the enzymes which are contained in some foods, such as the cereal grains, for the moisture and warmth of the paunch are favorable to enzyme action in general.

After rumination the reswallowed food passes chiefly into the manyplies, or third stomach, where it is further ground between the muscular folds before being forced into the fourth, or true stomach. In the latter the digestive processes are similar to those in the simple stomach, as previously described.

41. The small intestine.—In the small intestine the work of digestion proceeds even more vigorously than in the stomach. All classes of nutrients are attacked by the fluids it holds, and in it the digestive processes come to a close. The contents of the stomach, when received into the small intestine, consist of a semi-liquid mixture of undigested proteins, partially digested nutrients—proteoses and peptones, fats, sugars, starches, and celluloses—and waste matter. The small intestine receives digestive fluids from 2 outside organs, the liver and the pancreas, whose functions in nutrition are of the highest importance, and the food is also mixed with a secretion containing several enzymes which are produced by the intestine itself. Immediately on entering the small intestine the inpouring material is changed from an acid to an alkaline character thru rapid addition of the bile and pancreatic juice, both alkaline.

42. The pancreas.—The pancreas, or sweetbread, is a slender gland lying just beyond the stomach and connected with the small intestine by a duct. Its secretion, the *pancreatic juice,* varies in different animals, being thin, clear, and watery in some, and thick, viscous, and slimy in others. The pancreatic juice contains 3 enzymes—trypsin, amylase, and lipase.

Trypsin is an enzyme which, like pepsin, converts protein into proteoses and peptones. It has the power of further cleaving these 2 partially digested substances into *amino acids,* which constitute the ultimate useful nutrients which come from the cleavage of all the proteins of food stuffs thru digestion. The digestion of protein goes on much more thoroly in the small intestine under the influence of trypsin than it does in the stomach with pepsin. It is most interesting that trypsin is secreted by the pancreas in an inactive form, which will not digest protein. As soon as the pancreatic juice comes in contact with the intestinal wall, intestinal juice is produced, which contains a substance that changes the trypsin into the active digesting form.

Amylase, formerly called *amylopsin,* is a pancreatic enzyme which converts starch into glucose-like sugars.

Lipase, formerly called *steapsin,* is a pancreatic enzyme which splits fats into fatty acids and glycerin.

Ordinarily, when digestion is not going on there is no secretion by the pancreas. It has been found that if the mucous lining of the first part of the small intestine is treated with dilute hydrochloric acid, the pancreas at once pours out its secretion. It will be remembered that the contents of the stomach, at the time of their ejection from that organ into the small intestine, are strongly acid because of the hydrochloric acid of the gastric juice. This acid when it pours into the small intestine, acting on the lining of the latter, produces something which, when absorbed into the blood, calls forth the pancreatic secretion just when needed—a forceful illustration of how all the organs of the complicated digestive tract work in harmony.

43. The liver.—The liver, the largest organ in the body, has numerous duties in the digestion and metabolism of nutrients. While some of its functions will be dealt with in a later chapter, attention is here directed to its function in the digestion and absorption of the fats of foods.

Bile, the product of the liver, is a clear, greenish or golden colored fluid, alkaline in reaction, and extremely bitter in taste. The bile furnishes the alkalies which are necessary for the conversion of the fats of the food into soaps, that is, for changing them from an unabsorbable into a water-soluble and readily absorbable condition. It is of such nature that it readily forms an emulsion with fats, and in this form the latter present a very large surface for the action of the lipase of the pancreatic juice. The process of the decomposition of the fats into fatty acids and glycerin is greatly hastened by this means. In the presence of bile the fatty acids take on alkali and form soaps, which are soluble in water and can be absorbed into the walls of the intestine. After performing this important function the bile is not wholly excreted with the contents of the intestine, but is in part taken up by the circulation and again utilized. According to Colin, the liver of the horse secretes over 13 lbs., of the ox 5.7 lbs., and of the sheep 0.75 lb. of bile during each 24 hours.

44. The intestinal secretion.—The digestive fluid secreted by the mucous membrane of the small intestine contains several enzymes, the most important of which are erepsin and the invertases.

Erepsin is an enzyme of great digesting power which attacks and still further splits or cleaves those proteoses and peptones which have escaped such action by trypsin, likewise converting them into amino acids, the ultimate digestion products of the proteins.

The invertases, *sucrase, maltase,* and *lactase,* are enzymes which convert cane-, malt-, and milk-sugars into the more simple glucose-like sugars.

Thus into the small intestine are poured the complex bile; the 3 digestive enzymes from the pancreas—trypsin, amylase, and lipase; and finally erepsin and the invertases from its own walls. Water is also freely poured into the small intestine from its walls.

While in the small intestine, the food, which has been masticated in the mouth and partially digested in the stomach, is acted on by all the various fluids above described. That part of the food which thus far has escaped digestion is now vigorously and variously attacked, so that under ordinary conditions little that is useful is lost. The larger portion of all the digested material is absorbed from the intestine into its walls, and thus enters the body proper, as will be shown on pages 32-3.

45. The large intestine.—The large intestine receives the contents of the small intestine after the latter organ has ceased further effort at digestion. These contents consist of undigested matter, bits of indigestible substances of all kinds taken in with the food, bile salts which have escaped resorption, water, mineral salts, and fragments of the mucous lining of the small intestine. Mixed with these are some of the digestive juices of the small intestine. The large intestine elaborates little, if any, digestive fluid, but its walls contribute water and certain metabolic waste products, especially certain inorganic salts common to the tract. It is possible that some digestion may occur in the large intestine owing to traces of digestive enzymes coming from the small intestine, but such digestion is insignificant in amount. There is a constant interchange of water between the contents of the large intestine and the blood circulation, which results in the absorption of any soluble products, nutritive or otherwise, which may be formed in the large intestine either by digestion or bacterial action.

46. Special provision for the horse.—The horse, tho eating coarse food like the ox, has a small stomach and no paunch for specially preparing such food for digestion. In partial compensation it has a large caecum, or blind gut, which is a greatly enlarged portion of the alimentary tract, linking the small and large intestine. Into the caecum is passed much of the undigested matter, together with the enzymes of the small intestine. Here the digestive processes of the small intestine are prolonged, thus making up for his small stomach and lack of a paunch. The caecum of other farm animals is small and unimportant in digestion.

47. Digestion of fat.—Since the steps by which the food is prepared thru digestion for final use by the body are so numerous and complicated, it is well to now review the subject, dealing with the nutrients and what occurs with them, rather than considering the organs and solvents employed.

As has been stated, the fats of foods, no matter how finely divided, cannot directly enter the circulation, but must be changed in the following manner: One of the enzymes produced by the pancreas is the fat-splitting lipase, which breaks some of the fats in the food into glycerin and fatty acids. The bile is largely made up of alkaline salts, and with these the fatty acids react and form soaps. These soaps in turn form an emulsion with the unchanged fats, the emulsified fats presenting a large surface on which the lipase may act. Thus, it is believed that the fat which is finally absorbed is split into glycerin and fatty acids, the latter and the alkali of the bile forming soaps. These soaps and the glycerin are absorbed by the intestinal wall, in the cells of which they are reunited into fats and are contributed as such to the circulation. Some authorities hold, however, that a part of the fatty acids and glycerin formed by the splitting of neutral fats by lipase may be absorbed as such, without being first changed to soaps.

48. Carbohydrate digestion.—The digestion of either starch or sugars (other than those of glucose-like form) consists in converting them into glucose or glucose-like sugars, which are the only forms of carbohydrates that can be used in the body. Since the carbohydrates constitute a large portion of the food of animals, nature provides for their digestion in several parts of the alimentary tract. Carbohydrate digestion begins with the action of ptyalin on the starches of foods in the mouth, whereby they are converted into maltose. Ptyalin action continues in the first portion of the stomach, but ceases in the latter part of that organ. Sugars of glucose form may be absorbed from the stomach. Even the compound cane-, malt-, and milk-sugars may without change be absorbed from the alimentary canal in small amounts. If these compound sugars remain in the digestive tract an appreciable time, as usually happens, they are changed to glucose and glucose-like sugars. Thus most of the carbohydrates are absorbed from the alimentary tract in the form of glucose. Nearly all the carbohydrates are carried on from the stomach into the small intestine, which is the principal organ concerned in their final digestion. Here the starches which have escaped digestion in the mouth and stomach are acted upon by amylase, and the compound cane-, malt-, and milk-sugars are converted by the invertases into simpler glucose-like sugars.

When a human eats bread, or an animal consumes hay or corn, the starch of such food must all be changed to sugars before it can enter the body proper. With trifling exceptions all compound sugars are converted into glucose-like sugars. It is even held that milk sugar has no food value with birds, because their digestive tract provides no enzyme for breaking it up into glucose-like sugars which may be absorbed.

In the digestive tract no enzyme has been found which acts on cellulose or on the pentosans. Bacteria inhabiting the alimentary canal, however, attack these substances, especially in the paunch of ruminants and the caecum of the horse. Among the products of such bacterial decomposition are organic compounds, such as acetic and lactic acid, besides gases—marsh gas, carbon dioxid, and hydrogen. While these gases are of no value to the animal, there is little doubt that the other cleavage products are absorbed from the digestive tract and serve as nutrients. Smith[4] suggests that cellulose digestion may be brought about by ferments contained in the food itself. When artificially digested with strong sulphuric acid, cellulose is converted into a gummy product and finally into glucose. Because the goat and the ox can subsist for long periods on coarse straw, which consists largely of cellulose and pentosans, it is reasonable to hold that these substances have considerable nutritive value, tho the manner of their digestion is not yet fully understood.

49. Protein digestion.—In the process of digestion the protein compounds in the food are attacked first by pepsin in the stomach, and later by trypsin and erepsin in the small intestine. The action of these enzymes is to cleave the very complex protein molecules into simpler ones, during which process the split molecules take up water and become soluble. Proteoses and peptones are products of the cleavage of proteins, an example of which may be seen in the following experiment: If a fragment of the white part of a hard-boiled egg, which is a protein substance, is placed in a dish with dilute hydrochloric acid, a little pepsin added, and the whole kept at body temperature, in a short time the edges of the opaque egg mass will become swollen and transparent, the change gradually extending thru the whole fragment. After a time the mass will have entirely disappeared, and in its stead there will remain a clear solution. If this peptone solution is evaporated to dryness there will be left a yellowish, transparent mass resembling the dried white of an unboiled egg. This dry digested material, now a mixture of proteoses and peptones, is soluble in water the same as the white of egg; but if dissolved in water it will not solidify on heating, as does ordinary white of egg. This shows that the substance has been changed to something other than the protein, which coagulates or solidifies on heating. These proteoses and peptones have resulted from the cleavage or splitting of the very complex egg protein into simpler molecules, which upon such cleavage have taken up chemically a large amount of water and become sol-

[4]Manual of Vet. Physiol., 1908.

uble. When a piece of lean meat or hard-boiled egg is taken into the human stomach, the pepsin, acting in the presence of hydrochloric acid, gradually dissolves such meat or egg, changing it to soluble peptones and proteoses. If it escapes solution in the stomach, it is usually dissolved later in the small intestine.

The soluble proteoses and peptones are not yet in suitable form for use in the body of the animal, and so are not absorbed, but are retained in the small intestine until they have undergone further enzyme action. This is effected by trypsin, which can not only attack protein directly and convert it into proteoses and peptones, as does pepsin in the stomach, but can also attack the peptones and proteoses and cleave them further. Erepsin, an enzyme of the small intestine, is of powerful action. It attacks nitrogenous substances after they have become proteoses and peptones. By the action of these last 2 enzymes the proteoses and peptones have their molecules further cleaved into simpler but still complex molecules, water being again taken up as in the first cleavage. The simplest products of such cleavage of the proteins of food substances are the amino acids.

The *amino acids* are the common final nitrogenous nutritive materials of the digestive tract, resulting from the cleavage of the complex molecules of the food proteins. They are soluble in the juices of the small intestine and are ready for transference thru the intestinal walls into the body proper. These acids are still relatively complex in structure, but are much simpler than the proteoses and peptones from which they are derived. The amino acids, derived from the nitrogenous portion of foods, constitute the great primary nitrogenous building material out of which the protein tissues of the animal body are built. So far as known, protein compounds taken as food cannot be broken apart further than into amino acids and remain useful in body building.

50. Tissue building.—The process of protein digestion is the breaking down of complex nitrogenous bodies into simpler ones. A good picture of what takes place can be had by likening the protein molecule to a house being taken down by a builder in order that he may construct another from the materials. An animal eating protein compounds cannot use the protein molecules in the form in which the plant has built them up into its own substance, but must first take them apart to a greater or less extent, and from the parts reconstruct another kind of protein molecule suitable for its own use. In other words, its protein molecules must have a different architecture from those of the plants which serve as its food. The proteoses and peptones may be likened to the roof and walls of the house. These walls and the roof can be broken down into bricks and tiles, which are represented by the amino acids; and from these the animal, beginning anew, can construct new proteins of the specific architecture its body may require.

51. Bacteria.—In the stomach bacteria find unfavorable conditions for growth because of the free acid of the gastric juice, and in the small intestine the presence of bile rapidly causes the death of bacteria.

Consequently bacteria play little or no part in digestion in either the acid stomach or the alkaline small intestine. They do act, however, on the woody fiber or cellulose, and in some cases on soluble carbohydrates, in the first three stomachs of ruminants and in the caecum of the horse. In the large intestine there develops a profuse bacterial growth of various forms which thrive in the absence of air. The presence of more or less undigested food, together with moisture, warmth, and the faint alkaline reaction, furnishes ideal conditions for bacterial growth. Some cellulose is decomposed by the bacteria with the liberation of carbon dioxid, marsh gas, and hydrogen. Sulfureted hydrogen is also produced thru putrefaction of protein substances. Some nitrogen is found, but this has its source in the air taken in with the food. Much of the gas is doubtless absorbed into the circulation and eliminated from the lungs. Products other than gas which are mostly toxic or poisonous to the animal result in small quantity from bacterial growth in the large intestine. To these substances the odor of the feces is largely due. If the functions of the bowels are impaired, the contents may remain for an undue length of time, in which case excessive putrefaction may cause the animal to suffer from poisoning due to the absorption of the products formed.

52. Feces.—The solid excrement, or dung, of farm animals is that waste which finally escapes from the large intestine, the solids of which, for the most part, have never been within the body proper. It is composed principally of cellulose, or woody fiber, from the undigested portions of straw, hay, and grasses; and also of seeds, grains, or parts of the food that have escaped proper mastication and digestion. Matter not properly food, such as hair and dirt of various kinds taken into the alimentary tract, escapes thru this exit. Finally there are cast away traces of bile salts and some mucus from the lining of the intestines, together with much water.

53. Amid digestion.—The nitrogenous bodies of plants which are known collectively as "amids" are, as before stated, simpler nitrogenous compounds than proteins. They are either on their way to be built into proteins, or result from the cleavage of proteins in the plant for the purposes of transportation, or are formed in the partial breaking down and decay of protein. Very little is actually known of their chemical nature, but they are probably similar in character, in many instances at least, to certain intermediary products of digestion in the animal body. Since amids may result from enzyme action in the plant, their digestion in the animal may be looked upon as similar to that of proteins.

54. Mineral matter.—So far as known, the mineral matter, or ash, in foods is absorbed principally from the small intestine and is usually unchanged in chemical composition. Changes which occur in the different inorganic salts, or mineral matter, are entirely due to such chemical reactions as would have taken place outside the intestine under the same conditions. Insoluble mineral matter in food may become soluble because of the hydrochloric acid in the gastric juice of the stomach, but this is hardly to be regarded as digestion.

55. The work of the digestive glands.—The brilliant studies of the Russian physiologist, Pawlow,[5] and his associates, followed by others along similar lines, have thrown much light upon the subjects of digestion, appetite, and palatability. In order to study the processes of digestion, operations such as the following were performed on many dogs: (1) The ducts, or tubes, which deliver the saliva into the mouth were cut, turned outward, and healed into the cut edges of the skin, so that when saliva was secreted it poured out thru the opening and could be caught in glass tubes attached to the dog's head. (2) The gullet, which carries food from the mouth to the stomach, was cut across, led outward, and healed in the skin at the throat, so that when food was swallowed it would pass out at the severed end and fall back into the dish out of which he was feeding. Food so eaten was called a "false meal." In many cases a dog with a gullet thus severed would chew and swallow the "false meal" again and again with apparent satisfaction. (3) An opening was made thru the side of a dog and into his stomach. On the healing of the stomach wall with the cut in the skin, the investigator was enabled to pass food directly into the stomach and study the processes of digestion occurring within that organ. (4) A portion of the stomach was constricted and made into a small separate chamber, which likewise opened out thru the side of the dog. Here the flow of juices could be studied independent of admixture with food placed in the other portion of the stomach. (5) The small intestine was drawn to the side of the dog, and an opening made in it the same as in the stomach. (6) The pancreatic duct was cut and led outward, so that its secretion could likewise be studied. The animals usually yielded readily to the operations and lived comfortable lives, so that the results were normal.

It was found that the sight, smell, or taste of food not only started the flow of saliva in the mouth, but the gastric juice also began to pour from the walls of the stomach in about 5 minutes even when there was no food in that organ. The gastric secretions which are brought forth by the sight, taste, or smell of food are designated by Pawlow as "psychic secretions." For example, when a dog was given a false meal, and the swallowed food fell out of the fistula, or opening, in the throat and back into the dish out of which the dog was eating, the stomach would nevertheless pour forth its fluids (psychic secretions), as tho the food had reached it. The more eagerly the dog ate his false meal the greater was the amount of gastric secretions, and the richer they were in both acid and pepsin. The gastric secretions were strongest and most copious with that food which was liked best, and food given in small portions called forth stronger juices than when the whole ration was given at one time.

These psychic secretions do not last long enough to explain the long continued secretion of gastric juice when a normal meal is eaten.

[5] The Work of the Digestive Glands.

In studying other causes which might produce the secretion, it was found that no flow could be started by such mechanical stimulation as passing a feather or a glass rod over the mucous membrane of the stomach. Water caused a moderate flow of gastric juice, but when fat, egg albumin, starch, or sugar was introduced with water no greater flow resulted than with water alone. The juice of meat, however, called forth a marked flow. This explains the continuance of the secretion after the psychic secretion ceases. The gastric juice secreted as a result of the mental stimulus digests some of the protein of the food, thereby forming soluble nitrogenous compounds, which in turn stimulate the glands to further secretion.

The saliva secreted was thin and watery when sand or dry, powdered biscuit was placed in the dog's mouth, and much more concentrated when stones were introduced, which the dog could swallow without the aid of a large amount of saliva. The amount of saliva and gastric juice also depended on the nature of the food fed. Pawlow's work indicated that the enzyme content of the digestive juices depended on the kind of food, the glands being guided by a form of instinct, so that, for example, the pancreatic juice would contain more trypsin when meat was fed than when starch was supplied. However fascinating this idea is, after numerous more recent investigations the consensus of opinion is now against such an adaptation of the digestive juices to the food.

It is indeed fortunate that the character of the digestive juices of an animal are not changed with variations in the food consumed. Between meal times the secretory cells are elaborating the enzymes which are to be contained in the secretions that will be poured forth to digest the next meal. If the cells formed only enzymes suited to digestion of the previous meal, and the animal then consumed food of a different kind at the following meal, the juices might be unsuited to its digestion. It is therefore wise that no matter what food the animal consumes, the digestive glands pour forth the enzymes needed for the digestion of all the various nutrients.

56. Palatability.—So vague and illusive is the subject of the palatability of food that it would be a waste of space to discuss it at any length in this work. "What is one man's meat is another man's poison" is an old saying, to which might be added, "and what is one man's meat to-day may be his poison to-morrow"; for desire, appetite, and digestion are not the same with any given individual at all times and under all circumstances. Even with farm animals palatability is greatly influenced and controlled by familiarity and habit or custom. When corn silage is first placed before cows, not infrequently, after sniffing it, they will let it alone for a time. They then usually begin nibbling at it, and later may gorge themselves thereon if permitted. In such cases food that at first seems unpalatable suddenly becomes palatable.

In his early experience the senior author was feeding 2 lots of fattening steers, one on shelled corn and wheat bran, the other on wheat bran and shelled corn ground to a meal. After some weeks of successful feeding, the rations for the 2 lots were reversed. The steers changed from corn meal to whole corn showed a strong dislike for the new ration, eating so little at first that they shrank materially in weight. From this the general conclusion might have been drawn that shelled corn is less palatable than corn meal for fattening steers. But the steers given corn meal in place of shelled corn were equally dissatisfied. This shows that custom and habit—something entirely extraneous to the food—are possible factors in palatability.

While palatability has a bearing on digestibility, the reverse is not necessarily true, for humans and animals often show fondness for kinds of food that are indigestible or worse. Even poisonous substances may be palatable, and, on the other hand, food which the human or animal does not relish or even dislikes may have high nutritive value provided the repugnance thereto is overcome.

Despite the complexities of the subject, every practical stockman knows that to get the best results he must at all times provide feed for his animals which is palatable and altogether acceptable. This may be accomplished in considerable degree by steadily using the same feeds and feed combinations, and in always avoiding sudden and violent changes in their character and in the manner of feeding.

III. Metabolism

In the preceding division we learned how digestion prepares the nutrients of feeding stuffs for the nourishment of the animal body. In what follows there is briefly set forth how the digested materials are brought into the body proper and what becomes of them. Chemists and physiologists, working together with skill and great patience, have been able quite fully to set forth and explain the processes of digestion. When the nutrients leave the alimentary tract and enter the body, the difficulties of following them and learning what becomes of them are much greater. Many of the changes that occur in the body have been revealed by persevering scientists, but concerning others, only little of a definite nature can yet be told.

57. Metabolism.—The processes by which the digested nutrients of the food are utilized for the production of heat and work, or built up into the living matter of the body, in turn being broken down and once more becoming non-living matter, are termed *metabolism.* Constructive metabolism, or the building-up processes, is termed *anabolism,* while the breaking-down and wasting processes are styled *catabolism.*

58. The circulative canals of the body.—The body of the animal is made up of innumerable cells, which, grouped and modified in myriads of ways, ultimately form all its organs and parts. Everywhere among the cells are minute spaces called *lymph spaces,* which are connected with the *lymphatics,* a set of vessels which permeate most parts of the body. In some respects the lymphatics resemble the veins, but they are thinner and more transparent and drain in only one direction—toward the heart. Within these vessels is a clear fluid called *lymph.* These vessels unite with one another, forming a network in many places. Here and there a trunk subdivides into five or six smaller vessels, and the latter enter a nodule-like body called a *lymphatic gland.* From this gland come several small vessels, which, after a short space, again unite to form a trunk. Gradually these trunks unite, forming larger trunks until a large duct and another smaller one are formed which enter veins in the neck.

The other set of canals is the arteries and veins, which permeate every portion of the body, the former carrying the blood away from the heart, and the latter carrying it to the heart. At the extremities of the arteries are still more minute tubes, called *capillaries,* which connect them with the veins. If one extends his arms in front of him with his finger tips touching, his body will represent the heart, while one arm will represent an artery carrying blood from the heart, and the other a vein conveying blood to the heart. The touching fingers will correspond to the capillaries connecting the arteries with the veins, and the space all about the fingers will represent the surrounding body tissues. In general, neither the veins nor the arteries allow any substance within them to escape thru their walls proper. It is thru the capillaries that the nutritive matter carried by the blood finds its way into the body tissues for their nourishment, and thru the capillaries and the lymphatics, in turn, the waste of the body drains back into the blood circulation. The cellular tissues of which the body is composed are thus everywhere permeated by the ducts of the lymphatic system and the capillaries of the blood system. The cells of the body are bathed by lymph, which is the fluid that receives and temporarily holds all the nutritive substances and the body waste. The mucous membrane lining the small intestine has a velvety appearance, caused by innumerable minute, cone-like projections, or tongues, called *villi,* which project into the interior of the intestinal tube, thereby coming into contact with its fluid contents. Within each villus are *lacteals,* or drainage tubes of the lymphatic system, and capillaries of the blood system.

59. Absorption of fat.—As before told, in the small intestine a part of the fat of the food is split into fatty acids and glycerin by the action of lipase. These acids and the alkalies in bile combine to form soaps which aid in emulsifying the remaining fat, so that it also is rapidly acted on by the lipase and changed into fatty acids and glycerin. Modern investigation supports the view that the fats are all absorbed as soaps and glycerin. In the intestinal wall these are reconverted into neutral fats which enter the lacteals, forming with the lymph a milky substance called *chyle.* This is carried in the lymphatics and poured into a vein near the shoulder, thus entering the blood circulation.

60. Absorption of carbohydrates; formation of glycogen.—The glucose and glucose-like sugars taken up from the intestinal contents by the capillaries pass into the veins, and thence by way of the portal vein into the liver. Here they are for the most part withdrawn from the blood and temporarily stored in this organ as *glycogen,* a carbohydrate which is closely related to starch and, having the same percentage composition, is sometimes called animal starch. Normally from 1.5 to 4.0 per ct. of the weight of the liver consists of glycogen. The glycogen stored in the liver is gradually changed back into glucose, and then doled out to the system as required, the amount of glucose in the blood being kept at about 1 part in 1,000. The property of converting glucose into glycogen is not possessed by the liver alone, but by the tissues of the body generally, especially the muscles. When work is being done the glycogen in the muscles is first drawn upon to furnish glucose, and after this store has been exhausted, the glycogen in the liver furnishes the needed glucose.

61. Absorption of proteins.—It was formerly supposed that the amino acids, the products of protein digestion, which are absorbed from the small intestine thru the villi, were joined together while still within the intestinal walls, thereby forming the complex proteins of the blood called *serum albumin* and *serum globulin.* Thru refinement of experimental methods Van Slyke,[6] and Folin and Denis[7] have been able to prove that the amino acids are not necessarily thus built into blood proteins in the intestinal wall, but that they may pass into the blood stream without being united. They are then carried into the general circulation, and from the blood stream each of the various tissues of the body—muscles, organs, etc.—absorbs a certain amount of the amino acids for growth, or the repair of the daily waste of protein matter.

Mineral matter is taken up from the small intestines, and water is absorbed all along the alimentary tract, from the stomach to the large intestine.

62. Distribution of absorbed nutrients.—We have seen that the digested fats which are to nourish the body are poured into the blood current by way of the lymphatics, while the glucose and the amino acids enter the blood directly thru the capillaries and veins. The veins from the small intestine unite and become the portal vein, which passes the blood thru the liver and on into the heart. The various nutrient materials, having been mingled with the blood, are carried thru the circulation to the capillaries.

These are so constructed that, when the blood finally reaches them, the nutritive substances it carries pass thru their walls and are mingled with lymph that bathes the myriad body cells. In this manner all the nutrients, having been especially prepared and transported, are available for the nourishment of every portion of the body. Oxygen is taken into the blood thru the lungs, and water and mineral matters are absorbed from the digestive tract. All are carried by the arteries and pass thru the capillaries into the lymph.

[6] Jour. Biol. Chem., 12, 1912, 399-410; 16, 1913, 187-233.

[7] Jour. Biol. Chem., 11, 1912, 87–95; 12, 1912, 141–162.

63. Use of the absorbed nutrients.—The absorbed nutrients, thus transferred to all the tissues of the body, may be oxidized, or burned, to warm the animal, or to produce energy to carry on the vital processes and to perform work, as shown in the following chapters. In case more nutrients are supplied than are required for these purposes, the excess may be transformed into body tissue proper, as shown in Chapter V. The glucoses may be converted into fats and stored as body fat, as may also the fats derived directly from the food fats. The amino acids may be built up into body protein or, if not needed for this purpose, a portion of their carbon, hydrogen, and oxygen may be converted into fat, while the nitrogen is excreted, chiefly in the form of urea. The highest use of the proteins, however, is the formation of nitrogenous tissues—the muscles, brain, nerves, skin, hair, and various organs of the body.

64. Disposal of body waste.—In breaking up the food nutrients within the body proper for the production of heat, and in the changes which occur in building them into body tissues, carbon dioxid is evolved. Most of this escapes into the capillaries and is carried in the blood by the veins to the lungs, where it is eliminated in breathing, a portion, however, escaping by way of the skin. Some of the marsh gas produced by fermentations in the stomach of herbivora is absorbed into the blood and thrown out by the lungs.

Nearly all of the nitrogenous waste, representing the breaking down of protein material in the body, is excreted in the urine thru the kidneys, tho a trace is given off in the sweat and a more appreciable amount in the feces. In mammals this waste takes the form principally of urea. In calculating the total amount of protein metabolism it is customary to determine the total nitrogen in the urine and multiply this by 6.25. This gives the amount of protein broken down, since it is assumed that, on the average, nitrogen forms 16 per ct. of the total weight of the protein molecule. (17)

A great variety of other end-products of metabolism are likewise eliminated by the kidneys thru the urine. The inorganic salts, such as common salt, also escape from the body principally in the urine. Small amounts of most of the substances eliminated in the urine are also excreted by the skin thru the sweat glands. A considerable portion of certain inorganic salts containing calcium, magnesium, and phosphorus is eliminated by way of the intestines.

65. Summary.—In Chapter I we learned how the various inorganic compounds taken by plants from earth, air, and water are built into organic plant compounds, and how in such building the energy of the sun becomes latent or hidden in the substance of the plant. In this chapter we have learned how the animal, feeding on plants, separates the useful from the waste by mastication and digestion, and how the digested nutrients, after undergoing more or less change, are conveyed from the alimentary tract to the body tissues and used for building the body, for warming it, or in performing work. All the energy manifested by living animals and the heat evolved in their bodies represent the energy of the sun originally stored in food substances by plants. With the breaking down of the nutrient matters in the bodies of animals, and in the decay of the animal substance itself, the organic matter loses the condition of life and falls back to the inorganic condition, once more becoming a part of the earth, air, and water as inert matter. After this degradation it is again gathered up by the plants and once more starts on the upward path. Such is the eternal round of Nature, in which plants, animals, the energy of the sun, and the mysterious guiding principle of life all play their parts.

CHAPTER III

MEASURING THE USEFULNESS OF FEEDS

I. Digestibility of Feeds

In determining the relative usefulness of different feeding stuffs to the animal it is necessary to find a means of measuring the amount of nutrients which each actually furnishes. The most simple means for such measurement is to determine the digestibility of the several nutrients of a feed; i.e., the percentage of the total crude protein, fiber, nitrogen-free extract, and fat which is digested by the animal. The digestible matter is obviously the only portion of the feed which is of use, since the remainder passes out in the feces without ever having really entered the body. In studying the digestibility of a given feed the chemist first determines by analysis the percentage of each nutrient it contains. Weighed quantities of the feed are then given to the animal, and the feces voided during a stated period are saved and weighed, and samples are analyzed. The difference between the amount of each nutrient fed and that found in the feces resulting therefrom represents the digested portion.

66. A digestion trial with sheep.—To show how the digestibility of a feed is determined, the following results are given from an actual digestion trial conducted by Armsby at the Wisconsin Station.[1] Desiring to ascertain the digestibility of clover hay and malt sprouts, 2 wethers weighing 87 lbs. each were confined in specially constructed apartments and fed from zinc-lined boxes to prevent waste. Each day's allowance was weighed and samples analyzed. The feces voided by the wethers were collected in rubber-lined bags attached to their hind quarters by a light harness. These bags were emptied each 24 hours, and the contents weighed and analyzed. Feeding progressed 6 days before the trial proper began, in order that all residues of previous feed might have passed from the alimentary tract. During the first period each sheep, as shown in the table, was fed 700 grams (about 1.5 lbs.) of clover hay daily, which was consumed without waste.

Digestion trial with sheep fed clover hay; average for 1 day

	Dry matter	Crude protein	Carbohydrates		Fat
			Fiber	N-free extract	
	Grams	Grams	Grams	Grams	Grams
Fed 700 grams hay, containing..	586.1	77.7	191.5	276.7	10.7
Excreted 610.6 grams feces, containing..................	288.6	40.4	101.5	119.4	7.9
Digested.....................	297.5	37.3	90.0	157.3	2.8
Per cent digested..............	50.8	48.0	47.1	56.8	26.2

[1] Wis. Rpt. 1884.

The table shows that the 700 grams of hay fed contained 586.1 grams of dry matter, and that the feces for 1 day, which represented the undigested portion of the ration, contained 288.6 grams. The difference, 297.5 grams, or 50.8 per ct., is held to be the dry matter digested. The average dry matter digested in 2 such trials was 51.2 per ct. Of the 77.7 grams of crude protein supplied, 40.4 grams appeared in the feces. The difference, 37.3 grams, or 48 per ct., represents the digested crude protein. In like manner the percentage of the other nutrients digested was determined.

The average percentage of each nutrient digested in a feeding stuff is termed the *coefficient of digestibility,* or *digestion coefficient,* for that nutrient in the feed.

67. Digestibility determined by difference.—Ruminants and horses are not normally fed on concentrates alone. Therefore, when it is desired to determine the digestibility of a concentrate, the animal is first fed roughage alone and the amount digested determined. The concentrate to be studied is then added to the roughage, and the total nutrients digested from both feeds are found. By difference, the amount of digestible nutrients coming from the concentrate is computed.

To determine the digestibility of malt sprouts, the sheep used in the above trial were next fed a ration of 600 grams of clover hay and 175 grams of malt sprouts, as shown below:

Trial with sheep to ascertain the digestibility of malt sprouts

	Dry matter	Crude protein	Carbohydrates		Fat
			Fiber	N-free extract	
	Grams	Grams	Grams	Grams	Grams
Fed 600 grams hay	500.9	67.4	163.3	236.3	9.4
Fed 175 grams malt sprouts	154.1	36.8	21.0	87.5	2.2
Total	655.0	104.2	184.3	323.8	11.6
In 681.1 grams feces	295.2	41.5	100.6	129.0	5.5
Digested, total	359.8	62.7	83.7	194.8	6.1
Digested from hay	256.4	33.2	76.8	135.2	3.8
Digested from malt sprouts	103.4	29.5	6.9	59.6	2.3
Per cent digested	67.1	80.2	32.9	68.1	104.5

The digestibility of malt sprouts was determined indirectly in the following manner: The dry matter of the clover hay and malt sprouts together equaled 655 grams. The excreted dry matter from this equaled 295.2 grams, so that the total quantity digested was the difference, or 359.8 grams. In the previous trial it was found as the average of 2 periods that 51.2 per ct. of the dry matter in clover hay was digestible. Taking 51.2 per ct. of 500.9 grams gives 256.4 grams, which is the probable quantity of dry matter that was digested from the hay. Subtracting 256.4 from 359.8 grams, there is left 103.4 grams, or 67.1 per ct., which is taken as the per cent of dry matter digested from the malt sprouts. In a similar manner the other digestion coefficients for malt sprouts are determined. The table reports 104.5 per ct. of the fat of malt sprouts digested—an absurdity. The total quantity of fat in the feeds used in this trial was so small that an error like this could easily occur.

In digestion trials it is commonly assumed that all matter appearing in the feces has escaped the action of the digestive ferments and so represents the indigestible part of the food. Tho substantially correct, there are exceptions to this assumption. The feces contain some waste from the body itself, such as bile residues, matter which sloughs off from the walls of the alimentary tract, and unabsorbed digestive juices. In a metabolism trial with a goat at the Wisconsin Station fed a ration of straw, which is low in protein, Steenbock, Nelson, and Hart[2] found more nitrogen in the feces than in the original feed, due to the absorption of digestive juices by the bulky straw. Yet a considerable portion of the protein contained in the straw must have been digested.

By treating the feces with an acid solution of pepsin, all the nitrogenous compounds except the true undigested food protein may be dissolved therefrom, and the actual digestion coefficient thus found for the protein. In a few digestion trials in recent years this method has been employed.

Armsby has shown[3] that ruminants feeding on coarse forage convert much of the fiber into marsh gas, or methane, which has no nutritive value. In such cases digestion trials will show too high a value for the fiber.

In digestion studies the ether extract, or so-called fat, is determined by the use of ether, which dissolves not only the true fat, but also chlorophyll, wax, bile residues, and other substances which are not true fat. Due to this, and because the fats in feeding stuffs are usually in relatively small amount, errors are liable to occur in their determination. Fraps and Rather[4] at the Texas Station, on studying the ether extract obtained from 18 different forage plants, found that only 42 per ct. was true fat. The digestibility of the true fat averaged 66.4 per ct.; while only 29.1 per ct. of the remainder (not true fat) was digestible. The ether extract of seeds, which is nearly all true fat, is highly digestible.

68. Coefficients of digestibility.—The coefficients of digestibility for the various feeding stuffs, as determined by the experiment stations of this country, have been compiled by the authors and are presented in Appendix Table II. In the case of feeds for which American data are not available, coefficients from European sources have been included. From this extensive table the following examples are taken to show the digestibility of typical feeds:

[2] Jour. Biol. Chem., 19, 1914, p. 399. [4] Tex. Bul. 150.

[3] Cyclopedia Am. Agr., III, p. 65.

Coefficients of digestibility of typical feeding stuffs, from Appendix Table II

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat
				Fiber	N-free extract	
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Concentrates						
Dent corn	12	90	74	57	94	93
Oats	17	70	78	35	81	87
Wheat, ground	4	87	74	59	93	72
Wheat bran	20	65	78	31	72	68
Flax seed	7	77	91	60	55	86
Linseed meal, old process	3	79	89	57	78	89
Roughages						
Timothy hay	58	55	48	50	62	50
Red clover hay	25	59	59	54	66	57
Oat straw	18	54	28	60	51	39
Kentucky bluegrass, green	7	56	57	66	61	52
Corn silage	27	66	51	65	71	82
Mangels	22	87	70	37	95	..

The table shows that for dent corn 90 per ct. of the total dry matter, 74 per ct. of the crude protein, 57 per ct. of the fiber, 94 per ct. of the nitrogen-free extract, and 93 per ct. of the fat is digestible. Feeds which contain little fiber, such as corn and wheat, show high digestibility, because their nutrients are not protected from the action of the digestive juices by thick cell walls of cellulose, or fiber. Owing to their larger fiber content, oats and wheat bran are less digestible than corn or wheat. As a class the roughages are high in fiber, and therefore much less digestible than the concentrates. This will be noted on comparing the digestion coefficients for timothy hay and oat straw with those for corn and wheat. The dry matter of mangels is as well digested as that of wheat, again showing that roots are more like concentrates than roughages.

69. Digestible nutrients in feeding stuffs.—To determine the digestible nutrients in any feeding stuff the total amount of each nutrient in 100 lbs. thereof is multiplied by the digestion coefficient for that nutrient. For example, 100 lbs. of dent corn contain 10.1 pounds of crude protein (Appendix Table I), of which 74 per ct. is digestible, as shown by the preceding table. Accordingly, there are 7.5 lbs. of digestible protein in 100 lbs. of this grain. By this method the data contained in the extensive Table III of the Appendix have been computed. The following examples are here taken from this table for illustration and study.

In Appendix Tables I and II the fiber and nitrogen-free extract are given in separate columns, for, tho of the same chemical composition, these components often differ widely in digestibility. In preparing the tables showing the digestible nutrients in feeding stuffs, the digestible fiber and digestible nitrogen-free extract are determined separately and the results combined under the term *carbohydrates,* as is done in this table. The digestible carbohydrates in dent corn are computed as follows: According to Appendix Table I, 100 lbs. of dent corn contains 2.0 lbs. of fiber, 57 per ct. of which is digestible, as shown in Appendix Table II. Likewise there are 70.9 lbs. of nitrogen-free extract, 94 per ct. of which is digestible. Multiplying in each case and adding the products, we have 67.8 lbs., which is placed in the column marked "digestible carbohydrates."

Digestible nutrients in 100 lbs. of typical feeding stuffs, from Appendix Table III

Feeding stuff	Total dry matter	Digestible nutrients				Nutritive ratio
		Crude protein	Carbo-hydrates	Fat	Total (inc. fat x 2.25)	
Concentrates	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
Dent corn	89.5	7.5	67.8	4.6	85.7	1:10.4
Oats	90.8	9.7	52.1	3.8	70.4	1: 6.3
Wheat	89.8	9.2	67.5	1.5	80.1	1: 7.7
Wheat bran	89.9	12.5	41.6	3.0	60.9	1: 3.9
Flax seed	90.8	20.6	17.0	29.0	102.8*	1: 4.0
Linseed meal, old process	90.9	30.2	32.6	6.7	77.9	1: 1.6
Roughages						
Timothy hay	88.4	3.0	42.8	1.2	48.5	1:15.2
Red clover hay	87.1	7.6	39.3	1.8	51.0	1: 5.7
Oat straw	88.5	1.0	42.6	0.9	45.6	1:44.6
Kentucky bluegrass, green	31.6	2.3	14.8	0.6	18.5	1: 7.0
Corn silage, recent analyses	26.3	1.1	15.0	0.7	17.7	1:15.1
Mangels	9.4	1.0	6.1	0.1	7.3	1: 6.3

*The high value for flaxseed is due to the fact that its 29.0 lbs. of digestible fat equals 65 lbs. of digestible carbohydrates (29.0x2.25=65.2).

It will be noted that the typical feeds presented in this table show wide differences in the amount of different digestible nutrients they furnish. Corn and wheat are high in digestible carbohydrates and rather low in digestible protein, while wheat bran and linseed meal are high in digestible protein but low in digestible carbohydrates. Linseed meal contains more digestible protein and less than one-fourth as much digestible fat as the flax seed from which it comes. The roughages range lower in digestible nutrients than the concentrates. Oat straw is especially low in digestible protein, while immature and actively growing pasture grass will contain nearly as much digestible protein as wheat bran, if cut and dried to the same water content.

70. Nutritive ratio.—As protein serves special uses in the body, in discussions of feeding stuffs and rations the term nutritive ratio is used to show the proportion of digestible protein contained in comparison with the other nutrients. By *nutritive ratio* is meant the ratio which exists in any given feeding stuff between the digestible crude protein and the combined digestible carbohydrates and fat. It is determined in the following manner: The digestible fat in 100 lbs. of the given feed is multiplied by 2.25, because fat will produce 2.25 times as much heat on being burned in the body as do the carbohydrates. The product is then added to the digestible carbohydrates and the sum is divided by the amount of digestible crude protein, the quotient being the second factor of the ratio. The manner of computing the nutritive ratio of dent corn is as follows:

$$\frac{\underset{\text{Diges. fat}}{(4.6} \times \underset{\text{Heat equiv.}}{2.25)} + \underset{\text{Diges. carbohy.}}{67.8}}{\underset{\text{Diges. crude protein}}{7.5}} = \underset{\text{Second factor of nutritive ratio}}{10.4}$$

Nutritive ratios are expressed with the colon, thus, 1:10.4. The nutritive ratio of dent corn is therefore 1:10.4 (read 1 to 10.4); i.e., for each pound of digestible crude protein in corn there are 10.4 lbs. of digestible carbohydrates or fat equivalent. A feed or ration having much crude protein in proportion to carbohydrates and fat combined is said to have a *narrow nutritive ratio;* if the reverse, it has a *wide nutritive ratio.* Oat straw has the extremely wide nutritive ratio of 1:44.6, because of its low content of digestible protein compared with the carbohydrates and fat; oats the medium one of 1:6.3; and protein-rich linseed meal the very narrow ratio of 1:1.6, the carbohydrates being less than twice the crude protein.

When the total digestible nutrients (including fat × 2.25) in a feed or ration are given, as in Appendix Table III and this sample table, the nutritive ratio may be computed by simply subtracting the digestible crude protein from the total digestible nutrients, and dividing the remainder by the digestible crude protein. For example, the nutritive ratio of dent corn may be found thus: $(85.7-7.5) \div 7.5 = 10.4$, second term of nutritive ratio.

The term *carbonaceous feed,* which has recently come into common use, is a convenient designation for a feeding stuff having a wide nutritive ratio. Similarly, the term *nitrogenous feed* designates a feeding stuff having a narrow nutritive ratio.

II. Respiration Studies

Tables of digestible nutrients tell what part of the food may be digested and absorbed and thus really enter the body of the animal, but they throw no light on the use or disposition made of the nutrients when once they are within the body. To obtain such information the *respiration apparatus* has been devised. This is an air-tight chamber, arranged in such manner and with such devices that all that enters and comes from the body of the animal placed within it can be accurately measured and studied. In some cases mechanical work is performed, while in others the subject is at rest. Everything which passes into the animal—air, food, and water—is carefully measured and analyzed so that the exact intake of the body is known. The air is in turn drawn from the chamber and analyzed, and the solid and liquid excrements passed by the animal are all likewise weighed and analyzed. If the intake is larger than the outgo, the animal has increased in body substance; if less, it has lost. The respiration apparatus has been used for studying the production of work and the formation of the tissues of the body, both the lean flesh and the body fat. Thru this means scientists have, in some measure, been able to determine what becomes of the food animals consume.

71. A respiration study.—The use of the respiration apparatus is illustrated by the following example from Henneberg[5] of the Weende Station, Germany. A full-grown ox weighing 1,570 lbs. was placed in the respiration chamber. During one day of the trial it was fed 11.1 lbs. clover hay, 13.2 lbs. oat straw, 8.2 lbs. bean meal, and 2.13 oz. salt, and drank 123.7 lbs. water. The intake and outgo of the body for the day are shown in the following table:

One day's study with a 1570-lb. ox in a respiration apparatus

	Mineral matter	Carbon	Hydrogen	Nitrogen	Oxygen
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
A. Intake of body					
156.25 lbs. feed and water, containing					
27.94 lbs. dry matter	1.96	12.84	1.65	0.68	10.81
128.31 lbs. water	....	....	14.26	....	114.05
15.99 lbs. oxygen from air	....	....	....	....	15.99
172.24 lbs., total intake	1.96	12.84	15.91	0.68	140.85
B. Outgo from body					
120.25 lbs. excrements, viz:					
89.61 lbs. feces	1.27	5.69	9.28	0.23	73.14
30.64 lbs. urine	0.67	0.49	3.26	0.37	25.85
49.71 lbs. respiration products, viz:					
21.61 lbs. carbon dioxid	....	5.89	....	....	15.72
0.06 lb. methane gas	....	0.04	0.02	....	....
28.04 lbs. water	....	....	3.11	....	24.93
169.96 lbs., total outgo	1.94	12.11	15.67	0.60	139.64
A-B. Production in body					
0.48 lb. dry lean meat	....	0.25	0.03	0.08	0.12
0.62 lb. fat	....	0.48	0.08	....	0.06
0.02 lb. mineral matter	0.02	....	....	....	....
1.16 lbs. water in flesh and fat	....	....	0.13	....	1.03
2.28 lbs., total remaining in body	0.02	0.73	0.24	0.08	1.21

72. Intake of the body.—The first part of the table (A) shows that during the 24 hours of the trial the ox confined within the respiration apparatus took into his digestive tract 27.94 lbs. of dry matter in his food and 128.31 lbs. of water in food and drink, and breathed in air

[5]Neue Beiträge, Göttingen, I, 1870, p. XIX; Kraft, Lehrb. Landw., III, p. 17.

containing 15.99 lbs. of oxygen, a total intake for the day of 172.24 lbs. The amounts of mineral matter, carbon, hydrogen, nitrogen, and oxygen taken into the body in air, food, and water are shown in the respective columns of the table.

73. Outgo from the body.—The next division of the table (B) shows that during the day there passed from the ox 120.25 lbs. of excrements, of which 89.61 lbs. was feces and 30.64 lbs. urine. From the lungs and skin there was exhaled 49.71 lbs. of gas and vapor, somewhat less than half of which was carbon dioxid; a trace, methane gas; and the remainder, water.

Of the 12.84 lbs. of carbon contained in the ration, there was voided in the undigested matter of the feces 5.69 lbs., or about two-fifths the total amount. Similarly, about one-third of the nitrogen in the food never entered the body proper from the stomach and intestines, but passed away in the voidings. That part of the food which was digested and absorbed into the body was used to carry on the life functions and to repair the body tissues, or was stored as body substance.

The 30.64 lbs. of urine excreted contained 0.37 lb. of nitrogen. This nitrogenous waste came either from the food which the ox had consumed during the day, or resulted from the small, continuous wastage of the protein tissues of the body. Since about 16 per ct. of such protein matter as was contained in the food or composed the body tissues of the ox was nitrogen, by multiplying the 0.37 lb. of nitrogen by 100/16, or 6.25 (17), we find that 2.31 lbs. of the protein of the feed or from the body was broken down and passed away in the urine during the day.

74. Production in the body.—By subtracting the total outgo of the body from the total intake, we obtain the figures in the last part of the table, A-B. These show that out of 172.24 lbs. of food, water, and air taken in by the ox during the day, 2.28 lbs. remained as some part of the animal body. Of this, 0.02 lb. was mineral matter or ash; 0.73 lb. carbon; 0.24 lb. hydrogen, 0.08 lb. nitrogen, and 1.21 lb. oxygen. By multiplying the 0.08 lb. of nitrogen (more exactly, 0.077 lb.) by 6.25 we find that the steer gained 0.48 lb. of protein or dry lean meat. As protein is a little over half carbon, about 0.25 lb. of carbon was built into the lean meat, leaving 0.48 lb. of carbon to be stored as fat. Pure fat is about three-fourths carbon, hence the 0.48 lb. of carbon represents about 0.62 lb. of fat, which was stored during the day. As fresh lean meat is nearly two-thirds water, the 0.48 lb. of dry lean meat equaled 1.25 lbs. of fresh lean meat. The body fat of the ox is about two-thirds fat and one-third water; hence the ox stored about 1.0 lb. of fatty tissues during the day.

From this most instructive study we learn that a 1570-lb. ox confined in a respiration chamber for 24 hours consumed during that time 11.1 lbs. of clover hay, 13.2 lbs. of oat straw, 8.2 lbs. of bean meal, and 2.13 oz. of salt; drank 123.7 lbs. of water; and breathed in 16 lbs. of oxygen gas. From all this it gained 2.28 lbs. of body weight, of which about 1.12 lbs. was dry lean meat, fat, and mineral matter, and 1.16 lbs., or over one-half was water.

III. The Energy of Food

The living mature animal may be compared to a steam engine, in which part of the power derived from the fuel is used for the operation of the engine itself, i.e., the movement of flywheel, piston, etc., while the surplus may perform useful work. The steam engine derives its energy from coal or wood burned under the boiler; the animal, from the feed it consumes. Both require a small amount of repair material—steel, brass, etc., for the engine, and protein and mineral matter for the animal—but the largest demand with engine and animal alike is for fuel. It is therefore both important and interesting to consider the relative value of feeds in terms of the fuel they furnish the body.

75. Fuel value of feeds.—The value of any feeding stuff as fuel for the animal depends on the amount of energy which it will furnish when burned. As with coal, the fuel value of a feed is determined by burning a weighed quantity of it in pure oxygen gas under pressure in an apparatus called a *calorimeter.* The heat evolved is taken up by water surrounding the burning chamber and measured with a thermometer, the units of measure employed being the Calorie and the therm.

A *Calorie* (C.) is the amount of heat required to raise the temperature of 1 kilogram of water 1° C., or 1 lb. of water nearly 4° F.

A *therm* (T.) is 1,000 Calories, or the amount of heat required to raise 1,000 kilograms of water 1° C., or 1,000 lbs. of water nearly 4° F.

The fuel value of 100 lbs. of various substances, or the heat evolved on burning them, is as follows:

	Therms
Anthracite coal	358.3
Timothy hay, containing 15 per ct. moisture	175.1
Oat straw, containing 15 per ct. moisture	171.0
Corn meal, containing 15 per ct. moisture	170.9
Linseed meal, containing 15 per ct. moisture	196.7
Pure digestible protein	263.1
Pure digestible carbohydrates	186.0
Pure digestible fat	422.0

The table shows that, on burning, 100 lbs. of anthracite coal yields 358.3 therms, or enough heat to raise the temperature of 358,300 lbs. of water 4° F.; or about 8,000 lbs. of water from 32° F., or freezing, to 212° F., or boiling temperature. One hundred pounds of timothy hay likewise burned yields 175.1 therms, or about half as much as coal. Linseed meal has a higher fuel value than corn meal because it contains more oil. Digestible protein yields considerably more heat than the carbohydrates, and fat over twice as much as the carbohydrates.

The energy evolved on burning a substance may be expressed by the work it will do in lifting a weight, the unit of such measurement being the *foot-ton.* This is the amount of energy required to raise a weight of 1 ton 1 foot against the force of gravity. A *Calorie* will furnish the energy required to raise a weight of 1.53 tons 1 foot. A *therm* (1,000 Calories) will thus raise a weight of 1,530 tons 1 foot, or 1 ton 1,530 feet.

76. Available energy.—The fuel value of any feed does not necessarily measure its nutritive value to the animal, because feeds which yield the same number of heat units in the calorimeter may vary in the amount of available energy which they can furnish to the body. This is because:

1. A part of the food consumed passes thru the alimentary tract undigested. This may be compared to bits of coal dropping thru the grate of the boiler unburned.

2. The carbohydrates, especially woody fiber, undergo fermentations in the intestines and paunch, combustible gases being evolved which are without fuel value to the animal. (48) Even in well-constructed engines a similar loss of energy occurs in the combustible gases which escape thru the chimney without being burned.

3. When the protein substances in the body are broken down they form urea, a nitrogenous compound which is excreted by the kidneys. (64) Urea has fuel value which is lost to the body. Again we may liken this loss to that which occurs in the boiler thru the creosote which, tho having fuel value, is not burned in the fire box but escapes or is deposited in the chimney.

The fuel value of any food which remains after deducting these three losses represents the *available energy* of the food (or as it is now often called, the metabolizable energy). This is the portion which the animal can use for body purposes.

77. Net energy.—The available energy of the food measures its value for heat production in the animal, but does not represent its true value for other purposes. The animal must expend a part of the total available energy of any food in extracting the real fuel material from the relatively large proportion of useless material which it must excrete, and in converting the digested material into forms which can be used by the body. In other words, the work of masticating and digesting the food and of assimilating the digested nutrients requires considerable energy. The energy so expended finally takes the form of heat, but is not available for other purposes in the body, since the animal has no power to convert heat into other forms of energy. That portion of the energy which remains after masticating, digesting, and assimilating the food is termed the *net energy* of the food. This net energy is used by the animal, first of all, in the work of the heart, lungs, and other internal organs, and in case a surplus of net energy remains after satisfying the requirement of the animal for mere body maintenance, such surplus may be used for producing growth, fat, milk, or wool, or in the performance of external work.

The losses of energy due to mastication, digestion, and assimilation may be compared to the losses which would occur if a gasoline engine had to distil its own gasoline from crude petroleum and then get rid of the impurities which it could not use.

78. Net energy of feeding stuffs.—The respiration apparatus, previously described, furnishes a means by which the chemist may calculate the net energy of feeds from the amount of fat, protein, etc., deposited by the animal within its body during an experiment. In recent years the respiration apparatus of the earlier times has been improved by adding thereto means for accurately measuring the heat given off by the animal while under study. The new apparatus is styled the *respiration calorimeter.* The first respiration calorimeter in the United States was constructed by Atwater with the aid of the United States Department of Agriculture, at Middletown, Connecticut. It was for human nutrition studies only. The first and only respiration calorimeter for animals in this country was erected by Armsby some years since in a special building at the Pennsylvania State College, thru the joint efforts of the United States Department of Agriculture and the Pennsylvania Station.[6]

For many years Kellner[7] of the Möckern Station, Germany, employed the respiration chamber in animal studies. His studies and those of Armsby[8] with the respiration calorimeter have been for the most part with the mature ox. In these investigations not only was a record kept of all the feed consumed and water drank, but of everything that passed from the animal, including the so-called solid excrement, urine, carbonic acid gas, and water, and in the case of Armsby's experiments, all the heat given off by the body. While studies of this kind have really only begun, they have already brought out facts of great interest and importance. The following table sets forth some of their findings with reference to what becomes of the digestible nutrients and 3 common feeding stuffs when fed to the ox.

Net energy from 100 lbs. of digestible nutrients and common feeding stuffs

Nutrients or feeding stuffs	Total energy	Energy lost					Net energy remaining
		In feces	In methane gas	In urine	In production processes	Total loss	
	Therms	Therms	Therms	Therms	Therms	Therms	Therms
Digestible nutrients							
Peanut oil (fat)	399.2	0.0	0.0	0.0	174.4	174.4	224.8
Wheat gluten (protein)	263.1	0.0	0.0	49.2	118.3	167.5	95.6
Starch (carbohydrate)	186.0	0.0	18.8	0.0	68.7	87.5	98.5
Common feeding stuffs							
Corn meal	170.9	15.7	15.9	6.6	62.0	100.2	70.7
Timothy hay	179.3	87.7	6.8	5.5	52.9	152.9	26.4
Wheat straw	171.4	93.9	15.5	4.3	47.4	161.1	10.3
Expressed in per cent	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Corn meal	100	9.2	9.3	3.9	36.3	58.7	41.3
Timothy hay	100	48.9	3.8	3.1	29.5	85.3	14.7
Wheat straw	100	54.8	9.0	2.5	27.7	94.0	6.0

[6] For a popular description of these calorimeters, see Century Magazine, July, 1887, and the Experiment Station Record, July, 1904.

[7] Land. Vers. Stat., 53, 1900, pp. 440-468.

[8] U. S. Dept. Agr., Bur. Anim. Ind., Bul. 101.

This table sets forth some of the highest and most instructive attainments of the scientists working on problems in animal nutrition. The first column shows the total amount of energy which would be produced on burning 100 lbs. of the digestible nutrients or of typical feeding stuffs. With the digestible nutrients no further loss occurs in the feces, but all are absorbed out of the small intestine and go into the body proper. The oil contained no nitrogen, and so no nitrogenous waste from it appeared in the urine, nor did any of it form methane gas in the intestines. To digest and assimilate this 100 lbs. of oil required 174.4 therms of energy, leaving 224.8 therms which might be stored in the body, either temporarily in the lymph bathing the tissue cells, or more permanently as body fat.

When 100 lbs. or 263.1 therms of wheat gluten, which is principally protein, was digested and absorbed into the body, a loss of 49.2 therms occurred in the urine, this loss coming from the breaking down of this protein nutrient within the body, or from the breaking down of body tissue which was replaced by new protein from this source. In all 167.5 out of 263.1 therms in 100 lbs. of gluten were lost either in the urine or in carrying on the work of mastication, digestion, and assimilation, leaving 95.6 therms which might be temporarily or permanently stored in the body. This amount of protein was available for building protein tissues or lean meat, which would be its highest use, or it could serve for the production of body fat, etc.

79. Losses in undigested matter, methane, and urine.—Studying the lower division of the table we observe that if the total energy of corn meal is placed at 100, then 9.2 per ct. of its heat value passed from the ox in the undigested matter of the solid excrement. This loss we may compare to bits of coal passing unburned thru the grate bars of a furnace. While undergoing digestion, large quantities of methane gas were formed. This combustible gas was taken from the intestines by the blood and given off thru the lungs and skin, a loss of 9.3 per ct. resulting. There was a further loss of 3.9 per ct. in the urea which left the body in the urine by way of the kidneys. The sum of these three losses is 22.4 per ct., which measures that portion of the total fuel value of the corn meal which was of no value to the ox, but really worse than useless, because work was required in passing it thru the alimentary tract. The remaining 77.6 per ct. represents the available energy of the corn.

80. Losses due to mastication, digestion, and assimilation.—From this 77.6 per ct. of available energy must be deducted the energy expended in the work of mastication, digestion, and assimilation, amounting to 36.3 per ct. of the total fuel value of the corn. Subtracting this last sum and the previous losses from 100, there remains 41.3 per ct. as the net energy value of the corn, or the amount which the animal may use for repairing body tissue, for growth, for the laying on of fat, or for the production of external work. In the case of timothy hay only 14.7 per ct., and with wheat straw but 6 per ct., of its original fuel value remains as finally available for such purposes. About one-half of the total fuel value of these two feeds passed off as undigested matter, this portion never having been inside the body proper.

In noting the heavy losses shown under the column headed "Production processes," the following points are of interest: Zuntz found that the work of the horse in chewing hay and preparing it for swallowing required 4.5 per ct. of the total energy in the hay, oats only a little over 1 per ct., and corn but one-third of 1 per ct. He estimates that with the horse the work of digestion calls for about 9 per ct. of all the energy in the digestible portion of the food. He further found that each 100 lbs. of fiber, or the woody part of feeding stuffs, in passing thru the animal, whether digested or not, required about 118 therms for the work of disposing of it.

Such roughages as straw, hay, and corn stover, because of their coarse, woody character due to the fiber they contain, place much work on the animal in digesting them and passing the waste out of the body. This means an evolution of heat. Therefore where the animal, such as an idle horse in winter, is doing no work and needs little net energy, no harm but rather economy in cost of keep may result from living on such roughages, because the large amount of heat necessarily evolved in the digestion and assimilation of this food helps keep the animal warm. On the other hand, animals at hard work and those producing milk or being fattened cannot profitably subsist chiefly on coarse forage, for they need large amounts of net energy in their rations.

The data of the table we have been studying are as a whole correct, interesting, and helpful in extending our knowledge of a difficult, tho most important, subject in animal nutrition. In details they are more or less imperfect, and the student should not regard the figures in each division of the table as exact and final, but rather as approximate to the facts. Taken in the right spirit, these data are of the highest value in setting forth what portions of the food consumed by the animal are lost at each step in their progress thru the body, and showing how a considerable part of the value of the food is required to carry on the work of mastication, digestion, and metabolism, leaving a relatively small portion ultimately available for building the body or for external work. The marvel is that the scientists have been able to go so far in solving these most complicated problems, and that their zeal is still unabated.

IV. Factors Influencing the Nutritive Value of Feeds

81. Differences in composition of feeding stuffs.—The figures given in Appendix Table I for the composition of any feed are in most instances averages of all analyses of normal samples of that feed which have been reported by the various stations. It is obviously important to learn what variations from these averages may be expected in the case of samples of a given feed originating in different sections of the country, grown in different years, or when gathered at different stages of maturity. Lack of space prohibits any detailed consideration of this question. However, from the mass of data compiled in Appendix Table I, including over 53,000 analyses in all, from all parts of the country, the following notes will give a fair idea of the range in the chemical composition of typical feeding stuffs.

It has been found that the composition of a crop may be influenced to a limited extent by the amount of available plant food in the soil on which the crop is grown. Climatic environment and stage of maturity are, however, the most important factors in determining the composition of a given feed. Indeed, with some feeds they influence the content of nutrients to such a degree that an average of analyses from all sections of the country or at all stages of maturity is of little value for any purpose. Of the cereals, wheat is the most variable in composition, being profoundly influenced by climate, especially in its protein content. The analyses for this grain from different sections of the country are therefore given separately in Table I. It is there shown that while the average crude protein content of wheat from the northern plains states is 13.5 per ct., wheat from the Atlantic states contains only 11.7 per ct. and that from the Pacific states but 9.9 per ct. crude protein. The same extended study shows that climate exerts little or no influence on the chemical composition of corn, providing the crop matures, the average for the various sections showing no appreciable difference in content of the several nutrients. Grindley of the Illinois Station[9] has shown that samples of corn and wheat from the same region may vary 10 per ct. and sometimes even more in their content of protein or fat. The nitrogen-free extract is less variable, while fiber shows still larger differences than protein or fat. The same general tendencies as to local variations hold with the other cereal grains.

The roughages are even more variable in composition than the cereals, owing to the fact that, besides climate, their composition is influenced by the stage of maturity, the manner of curing, and the moisture content. Analyses of corn fodder and corn stover show a water content ranging from over 50 per ct. in field-cured material in wet seasons down to 10 per ct. or less in arid regions or where cured under cover in a dry season. To show the difference in nutritive value of these extremes it may be stated that corn fodder or stover containing 10 per ct. water will carry 80 per ct. more nutrients per 100 lbs. than a sample of the same forage containing 50 per ct. water! To overcome this error so far as possible, separate averages are given for very dry and for ordinary field-cured samples of these feeds in Appendix Table I.

The general rule that immature plants contain a much larger *proportion* of crude protein than when mature is well illustrated by analyses of samples of alfalfa cut at various stages of maturity by Dinsmore at

[9] Ill. Bul. 165.

the Nevada Station[10] and cured until they were somewhat drier than normal hay. The dried alfalfa cut when 3 inches high, a stage at which it is often grazed, carried 34.6 per ct. crude protein and only 43.4 per ct. total carbohydrates. As the crop matured the protein content of the hay therefrom decreased and the carbohydrates increased till the sample cut when seed was beginning to form contained only 14.1 per ct. crude protein, while the carbohydrates had increased to 68.1 per ct. Immature plants usually contain much more water than the same plants when more mature. On account of such wide differences in composition the authors have, wherever possible, given in Appendix Table I the averages for roughages at different stages of maturity. (See averages for corn fodder, timothy hay, Kentucky bluegrass, red clover, etc.)

It is shown in later chapters that as the grasses and legumes mature their content of fiber materially increases, and as a consequence the feed becomes less digestible and usually of lower value. However, the large accumulation of starch which occurs in the corn plant as it ripens gives the more mature form of that plant a greater total feeding value. (**27**)

If green forage is cured without waste and in a manner to prevent fermentation, the mere drying does not lower its digestibility. Ordinarily, however, in curing forage much of the finer and more nutritious parts is wasted, and dews, rain, and fermentations effect changes which lower digestibility. The large amount of work done in masticating dry forage and passing it thru the alimentary tract explains why green forage may give better results and hence appear more digestible than dry forage. The long storage of fodders, even under favorable conditions, decreases both their digestibility and palatability. Hay browned by heating shows increased digestibility of fiber but decreased digestibility of crude protein and nitrogen-free extract.

82. Influence on digestibility of amount of feed eaten.—Animals tend to digest their food somewhat more completely when given a maintenance ration than when on full feed. This may be due to the more rapid movement of the food thru the digestive tract or to a less complete absorption of the digested nutrients when present in large amount. Jordan[11] found that sheep digested 4.7 per ct. more of the dry matter when given a half ration than when fed a full ration. Mumford, Grindley, Hall, and Emmett[12] of the Illinois Station, on feeding steers clover hay and corn in varying proportions, found that those fed a maintenance ration digested 75.4 per ct. of the dry matter; those fed one-half more, 71.6 per ct.; those fed twice the maintenance ration, 69.4 per ct.; and others on full feed, consuming two and one-fourth times as much as the first lot, 65.9 per ct. of the dry matter of the ration. The difference in digestibility was greatest in the case of the carbohydrates. The steers on full feed digested the crude protein and fat nearly as well as those getting the maintenance ration. Eckles[13] of the Missouri Station found that the

[10] Nev. Rpt. 1907.
[11] N. Y. (Geneva) Bul. 141.
[12] Ill. Bul. 172.
[13] Mo. Res. Bul. 7.

dairy cow digests a maintenance ration somewhat better than a heavy ration. Under normal conditions, in feeding farm animals for the production of meat, milk, or work, other economic factors, which will be treated in later chapters, more than offset the slightly better utilization of feed when a scant ration is fed.

83. Influence of preparation of feed on digestibility.—Grinding, cracking, and rolling grain increase digestibility only in the case of hard seeds which would otherwise pass thru the digestive tract unbroken, or with animals unable to chew their food properly. Jordan[14] states that crushing or grinding grain for horses may increase its digestibility as much as 14 per ct. In extensive trials at the Iowa Station with 60-lb. pigs, Evvard[15] found that grinding or shelling corn did not increase the digestibility over that for ear corn. With 200-lb. pigs grinding alone increased the digestibility 0.8 per ct., and both grinding and soaking 1.9 per ct. Tho this trial shows a slight advantage from soaking feed, other tests show no appreciable gain from soaking or wetting feeds, except where such preparation aids in the mastication of unground hard seeds. Cutting or chaffing hay or straw does not increase digestibility, but may be advisable for other reasons, as is pointed out in Chapter XVI.

Cooking usually lowers the digestibility of the crude protein of feeding stuffs. At the Oregon Station,[16] Withycombe and Bradley found that steaming both vetch and corn silage materially decreased the digestibility of the crude protein and other nutrients. Cooking, steaming, or fermenting food, while often improving its palatability, generally lowers its digestibility, tho potatoes and possibly other starchy tubers are improved thereby.

A comparison of the digestion coefficients for various kinds of silage with those for the green forages from which the silage was made shows that ensiling tends to decrease digestibility. The exceedingly favorable results from silage feeding are therefore due to the palatability of the silage, its beneficial effect on the health of the animals, and the fact that less feed is wasted than when dry fodder is used.

Neither the frequency of feeding, the time of watering, nor the amount of water drunk appears to influence digestibility. Moderate exercise tends to increase digestibility, but excessive work lowers it.

The flow of saliva and the other digestive juices is checked by fright. On the other hand, kind treatment and palatability of food should favorably influence digestion. Under skillful care animals show remarkable relish for their food, and it is reasonable to conclude that better digestion ensues, tho no confirmatory data can be given.

84. Influence of proportion of the several nutrients.—The addition of a large quantity of easily digested carbohydrates, such as sugar and starch, to a ration containing much roughage may reduce the digestibility of its crude protein, fiber, and nitrogen-free extract. According

[14] The Feeding of Animals, p. 133.

[16] Ore. Bul. 102.

[15] Information to the authors.

to Kellner,[17] such *depression of digestibility* occurs with ruminants when less than 1 part of digestible crude protein is present to every 8 parts of digestible non-nitrogenous nutrients (carbohydrates plus fat $\times$ 2.25). With swine the nutritive ratio may be wider before the digestibility is affected. An explanation offered for such depression of digestibility is that when a large proportion of soluble or easily digested carbohydrates is fed, the bacteria in the digestive tract which normally decompose cellulose to secure food then attack instead the more readily available sugars or starch. (40) Not only is the digestibility of the cellulose, or fiber, consequently lowered, but also that of the crude protein and nitrogen-free extract, for the unattacked cellulose cell walls protect the proteins and carbohydrates contained therein from the action of the digestive juices. This depression does not occur when nitrogenous feeds, such as oil meal, are added along with the starch or sugar, thus preserving the balance between protein and non-nitrogenous nutrients. It is assumed that this is due to a stimulation of the bacteria by the addition of more protein, so that, invigorated, they attack the fiber of the food again.

Adding nitrogenous feeds to roughages, such as hay, straw, etc., does not increase the digestibility of the roughage. Neither does the addition of fat to a ration increase the digestibility of the other constituents. Kellner[18] states that supplying fat in excess of 1 lb. per 1,000 lbs. live weight or feeding pure fat or oil in unemulsified form may cause digestive disturbance. Salt does not affect digestion, tho it may cause animals to eat more food and may improve nutrition.

The addition of dilute acids, such as sulphuric acid or lactic acid (the chief acid in sour milk and in silage), does not influence digestibility. This is important in view of the fact that silage contains considerable free acid.

85. Class of animal, age, and breed.—Ruminants—the ox, cow, sheep—digest the same kind of forage about equally well. Kellner,[19] however, shows that the ox is able to digest as much as 11 per ct. more of the less digestible roughages, such as straw, than is the sheep. He ascribes this difference to the fact that the contents of the last part of the intestine of the ox remain more watery and hence are subject to more complete fermentation. The more easily digested a feeding stuff is, the less difference will there be in its digestion by these various animals. For the great majority of feeding stuffs the same digestion coefficients may be used for the sheep and ox.

The horse and pig digest less fiber than the ruminant, in whose paunch the coarse feeds undergo special preparation and digestion. The richer the feed, the more nearly do the digestive powers of the horse approach those of other farm animals. Swine digest the concentrates fully as well as do the ruminants, but make only small use of the fiber.

[17] Ernähr. landw. Nutztiere, 1907, p. 55.
[18] Ernähr. landw. Nutztiere, 1907, p. 51.
[19] Land. Vers. Stat., 63, 1906, p. 313.

In general, age does not, in itself, influence digestibility, tho young farm animals cannot utilize much roughage until their digestive tracts are developed. Evvard found at the Iowa Station[20] that while 200-lb. pigs digested ground corn as completely as did 60-lb. pigs, they digested 1.58 per ct. less of the dry matter of shelled corn than did the younger pigs. This small difference was probably due to less thoro mastication of the shelled corn by the older pigs. The digestion of old animals is often indirectly impaired by poor teeth, which make the proper mastication of their food impossible. Breed has no influence upon digestibility. Individual animals may, however, show considerable difference in their ability to digest the same ration, tho ordinarily the digestibility of a given ration by different animals of the same race will not vary by more than 3 to 4 per ct.[21]

86. Summary.—The foregoing discussions make it evident that average figures for the composition of any feeding stuff are but approximately correct when applied to a particular lot of the feed. This likewise applies to the expression of its nutritive value, whether stated in terms of digestible nutrients or net energy. In other words, different lots of any feeding stuff vary in feeding value, the same as different samples of coal vary in fuel value. Owing to the expense of obtaining analyses it is out of the question for any but the most extensive feeders to have their particular feeds analyzed, just as only the large manufacturer can afford to have samples of coal analyzed to determine their fuel value before purchasing. With the cereals and the roughages the general feeder must, therefore, rely on that average given in tables of digestible nutrients or net energy which corresponds most closely in his judgment to the feed at hand. In purchasing commercial concentrates, now sold in vast quantities everywhere, it is now fortunately possible in most sections of the country to secure standard brands, whose composition is fully guaranteed by the manufacturer. (Chapter **XI**)

[20] Information to the authors.

[21] Kellner, Ernähr. landw. Nutztiere, 1907, p. 46.

CHAPTER IV

MAINTENANCE OF FARM ANIMALS

I. Requirements for Body Fuel

Farm animals are supplied with food in order that they may convert it into such products as meat, milk, wool, and work, which are useful to man. However, as Armsby[1] points out, just as a factory must be supplied with power sufficient to keep the machinery in motion before any product can be turned out, to make continued production possible with the animal, enough food must first be provided to maintain all essential life processes. This amount of food, which is required merely to support the animal when doing no work and yielding no material product, is called the *maintenance ration.* A respiration trial conducted with an animal receiving a maintenance ration would show that the body was neither gaining nor losing protein, fat, carbohydrates, or ash. (**71**)

On the average, fully one-half of all the feed consumed by farm animals is used simply for maintenance, only the remaining half being turned into useful products. Knowing this, the intelligent feeder will realize that it is as important to understand the principles governing the maintenance requirements of his animals as those controlling the production of meat, milk, or work. The determination of the minimum amount of nutrients required for maintenance is also of great scientific importance, for it is impossible to find the true relative value of feeding stuffs for production without first subtracting the amounts used in mere maintenance.

To maintain an animal at rest sufficient food must be supplied to furnish: (1) Fuel to maintain the body temperature; (2) energy to carry on such vital processes as the work of the heart, lungs, etc.; (3) protein to repair the small daily waste of nitrogenous tissues; (4) mineral matter to replace the small but continuous loss of these materials from the body. Since the greater part of the food in a maintenance ration serves simply as fuel to maintain the body temperature, we will first show how the animal body is warmed and discuss its fuel requirements.

87. Body temperature.—While cold-blooded animals maintain their temperature but little above that of the surrounding air or water, the temperature of warm-blooded animals is usually much higher than that of the air. As shown in the following table the normal temperature of farm animals ranges from 98.4° to 105.4° F., a height which the air reaches only during the hottest summer days. It is therefore evident that

[1]Penn. Bul. 111.

heat must be continuously produced within the body to maintain these temperatures.

Normal temperatures of farm animals

	Deg. Cent.	Deg. Fahr.
Horse	36.9–38.2	98.4–100.8
Ox	38.0–39.3	100.4–102.8
Sheep	38.4–41.0	101.3–105.8
Pig	38.2–40.7	100.9–105.4

The normal temperature of different animals of the same species may vary considerably, as is shown by the table. On the other hand, the temperature of an individual animal, if healthy, varies only within a narrow limit, a departure of even 1 degree from normal with farm animals generally indicating some bodily derangement.

88. Heat production.—Heat is produced by all the decompositions or oxidations taking place in the body, whether of food yet within the digestive tract or of nutrients in the muscular tissues or the glands. We have seen that much heat may be evolved, especially with ruminants, in the decomposition of cellulose and other plant compounds in the digestive tract. (80) The remainder is produced in the tissues of the body by the following processes: Thru breathing, the oxygen of the air is brought to the blood. Floating in the blood stream are myriads of microscopic bodies, called red blood corpuscles, which owe their color to hemoglobin, an iron-containing protein. This hemoglobin absorbs the oxygen and holds it loosely. As the oxygen-laden blood permeates the capillary system it gives up the oxygen to the living body cells, where it is used for the combustion of a portion of the body nutrients with the result that heat is formed.

Unlike the burning of fuel in a stove, the oxidations in the body take place at a low temperature. As a result of the combustion in the body, where before there were glucose, fats, and proteins in the tissues, there now remain carbonic acid gas, water, and urea, the latter substance representing the principal nitrogenous waste of the protein nutrients. In still another respect body oxidations differ radically from ordinary burning of fuel. In a furnace the wider the draft is opened, increasing the supply of oxygen, the more rapid will be the combustion. In the body, however, so long as there is a normal supply of oxygen the rate of burning of the food nutrients is independent of the supply of air. Hence the greater intake of oxygen in unusually deep breathing will not in itself cause an increase in heat production, tho the increased muscular work in such breathing may lead to an increased production of heat.

As we have seen before (80), all the energy expended in the various forms of internal work of the body is finally transformed into heat. Even with such an easily masticated and digested feed as corn, over one-third of the total energy which the digestible nutrients furnish is converted into heat in the internal work of masticating, digesting, and assimilating the feed. This proportion is much higher with the roughages, such as hay and straw, which demand more energy for mastication and digestion. Tho this energy is lost so far as useful production is concerned, the heat evolved helps maintain the body temperature. With animals exercising normally, the larger part of the body heat is generated in the muscular tissues, since all muscular contraction is brought about by the oxidation or burning of body nutrients. Even when the muscles are not actively contracting, heat is being generated in them. The heat produced in the various parts of the body is more or less equalized, chiefly by the circulation of the blood. Generally, however, the temperature in the different parts varies somewhat according to their activities.

89. Production of heat in starvation.—When food is withheld from an animal, the heat needed to warm the body, the energy required to carry on the vital processes, and the protein and mineral matter necessary for the repair of the active tissues must all come from nutrients previously stored within the body. The small supply of glycogen in the liver and muscles is probably first used as fuel, but this is soon gone. (**60**) Fat is the animal's chief reserve fuel, stored when food is abundant, against times of scarcity, and is therefore the main source of both heat and energy during starvation. When the supply of fat begins to fail, the muscles and other protein tissues are broken down more rapidly to furnish heat and energy, and the animal finally perishes thru the impairment of its organs and the lack of body fuel to carry on the functions of life. Carnivora, or flesh-eating animals, withstand hunger longer than herbivora. While dogs and cats have lived until their weights were decreased 33 to 40 per ct., horses and ruminants will die when their weight has been reduced 20 to 25 per ct.[2] Men have voluntarily fasted for over a month, and dogs have survived fasts of from 90 to 117 days without permanent ill effects.[3] The age of the animal also influences the time at which death occurs from starvation, young animals losing weight more rapidly and dying after a smaller loss of weight than old ones.[4]

90. Heat regulation.—If heat were lost from the body by radiation only, as from a warm stone, it would be impossible for the animal to keep its temperature constant under varying external conditions and with daily supplies of food differing in amount and heat producing power. The body, however, possesses most effective means for controlling both the production and the loss of heat, this two-fold regulation being under the control of the nervous system.

The production of heat is regulated by increasing or decreasing the oxidations taking place in the body. The amount of heat generated is controlled more or less voluntarily by regulating the exercise taken and the amount of food consumed. Experience reminds us that on cold

[2] M. Wilckens in v. d. Goltz, Hand. d. ges. Landw., III, p. 88.

[3] Armsby, Penn. Bul. 111; Howe, Mattill, and Hawk, Jour. Biol. Chem., 10, 1911, pp. 417–432.

[4] Halliburton, Chem. Physiol., p. 834.

days we eat more heartily and walk more briskly than in warm weather. The degree of external heat or cold also causes an involuntary rise or fall in heat production. The shivering of a chilled animal is the outward manifestation of increased muscular contraction, started solely to produce more heat.

Controlling the amount of heat lost from the body is the second means of heat regulation. This is accomplished in part by varying the distribution of the blood on the surface of the body, and thus controlling the amount of heat lost from the skin by radiation and conduction. The loss of heat is further regulated by the production of sweat and the vaporization of water from the lungs. The clothing of man and the thick skin, hair, wool, and feathers of animals also check and control the loss of heat.

According to Howell,[5] the heat lost from the human body escapes as follows:

Avenues of escape of heat from human body

	Per ct. heat lost
By urine and feces	1.8
By warming expired air	3.5
By vaporizing water from lungs	7.2
By evaporation of water from skin	14.5
By radiation and conduction from skin	73.0
Total	100.0

The relative importance of these channels of heat loss depends upon various conditions and upon the species of animal. Animals that do not sweat give off more heat by the lungs and less by the skin. In proportion to their weight, small animals lose more heat by radiation than do larger ones of the same species. High external temperature tends to diminish the loss by radiation and increase that due to evaporation from the skin or vaporization from the lungs. Violent exercise calls for the rapid burning of food and tissue fuel, with a consequent increase of body heat. This heat passes off thru the more rapid breathing and the increased losses from the skin.

Because the loss of heat is largely controlled by the clothing he wears, man has, in some measure, lost his power of heat regulation. With many of the warm-blooded animals, however, this power is highly developed, as is shown by Rubner,[6] who determined the heat lost by a small dog at various air temperatures, before and after removing his coat of long hair. Before the dog was clipped lowering the temperature from 86° to 68° F. caused no increase in the loss of heat. After clipping, however, this change in temperature caused a 58 per ct. greater loss of heat, which was covered by increased production of heat in the body.

91. Heat and energy required for maintenance.—Experiments have shown that with a mature animal being maintained at rest in the stall the requirement for fuel to keep up the body temperature ordinarily

[5]Text Book of Physiol., 1907, p. 861.
[6]Gesetze des Energieverbrauchs, 1902, p. 14.

greatly exceeds the amount of net energy needed for the internal work of the body organs.[7] As will be shown later (448), Zuntz found that to maintain the horse at rest only one-third of the total energy of the ration need be supplied in the form of net energy, the remainder serving simply as body fuel. Hence, excepting for the pig, the maintenance ration of farm animals may consist largely of roughages, such as hay and straw, which furnish abundant heat, but do not yield much net energy. (78–80) Since the ration must furnish at least a minimum amount of net energy, animals cannot be maintained on such feeds as wheat straw alone, which furnish no net energy to the horse and but little to the ruminant.

Due to differences in temperament there is considerable variation in the maintenance requirements of different individuals of the same size and species, kept under the same conditions. As restlessness causes greater muscular activity and thereby uses up more body fuel, a quiet animal requires less food for maintenance than a nervous, active one. During experiments with a horse in a respiration chamber, Zuntz and Hagemann[8] found that the presence of flies caused the animal to give off over 10 per ct. more carbonic acid gas than normally, which means that this much more food fuel was burned. Armsby[9] found that the ox in the respiration calorimeter produced over 30 per ct. more heat when standing than when lying down. Some of this additional heat was undoubtedly produced thru the work of maintaining the body upright, but the larger part was due to the greater muscular movement of the animal when standing. Kellner[10] shows that the ox in good condition, especially when fat, requires a larger ration for maintenance than a lean one of the same body surface.

The loss of heat and energy from the body is not proportional to the size or weight of the animal, but rather to the body surface. This is shown by Rubner,[11] who determined the quantity of heat given off daily by fasting dogs of different sizes but in the same bodily condition, as reported in the following table:

Heat given off by fasting dogs of different sizes

Body weight	Body surface	Heat lost daily	
		Per kgm. wt.	Per sq. m. surface
Kgms.	Sq. m.	Cal.	Cal.
3.2	0.24	88.1	1212
6.5	0.37	66.1	1153
9.6	0.53	65.2	1183
18.2	0.77	46.2	1097
24.0	0.88	40.9	1112
31.2	1.07	36.6	1036

[7] Kellner, Ernähr. landw. Nutztiere, 1907, p. 405.
[8] Landw. Jahrb., 23, 1894, p. 161.
[9] Proc. Soc. Prom. Agr. Sci., 1902; Proc. Amer. Soc. Anim. Prod., 1914.
[10] Landw. Vers. Stat., 50, 1898, p. 245; 53, 1900, p. 14.
[11] Ztschr. Biol., 19, 1883, p. 535.

It is shown that while the heat lost daily per square meter of body surface remained nearly constant, the larger the animal the smaller was the daily loss per kilo of body weight. This is because large bodies have less surface in proportion to their weight than small ones, and the loss of heat from the body is largely determined by its relative surface. Hence maintenance rations should be proportional to the surface of the body rather than its weight. Since it is difficult to actually measure the surface of an animal's body, the maintenance ration for animals of different sizes may be computed by the well-known geometrical law that the surfaces of solids are proportional to the squares of the cube roots of their weights.

The rate at which heat is lost from the body by radiation also depends on the difference between the air temperature and the body temperature. Exposure to cold winds, especially with animals having scant coats, greatly increases the radiation of heat. Animals with coats wet by cold rain or snow lose additional heat from their bodies, for the cold water which falls on them must be warmed and evaporated by heat generated thru the burning of food. With the well-fed fattening animal, the greater loss of heat thru these causes may not produce any waste of food, for much more heat is being generated in the mastication, digestion, and assimilation of the heavy ration than is normally needed to warm the body. In the case of animals on a maintenance ration, whose chief demand is for body fuel, such exposure will necessitate an increased consumption of feed to serve as fuel. On the other hand, too high a stable temperature leads to loss of appetite and induces sweating.

II. Requirements for Protein

92. Protein waste from the body.—In view of the high cost and relative scarcity of crude protein in feeding stuffs, it is important to know the minimum amount of this nutrient required for maintenance. There is at all times an excretion of nitrogen from the animal body by way of the urine. With a well-nourished animal this excretion is relatively large, the amount depending chiefly upon the quantity of nitrogen supplied in the food. If all food is withheld from such an animal, the nitrogen excretion decreases rapidly at first, until the supply of amino acids in the blood and tissues, which have not yet been built into body protein, is lowered to a minimum. The nitrogen waste in the urine then slowly decreases until it reaches a level which remains quite constant so long as heat and energy are furnished by the body fat. When the supply of the latter begins to fail, the muscles and other protein tissues must thereafter not only furnish protein for the repair of the vital body machinery but must also supply the necessary heat and energy; consequently they waste more rapidly until death follows.

When animals are fed exclusively on nitrogen-free nutrients, such as the sugars, starches, fats, etc., the waste of fat from the body is materially lessened, and the waste of the nitrogenous tissues of the body, such as the muscles, is somewhat reduced, tho not entirely stopped. On account of this sparing of the body substances, animals forced to live on such diet survive longer than those wholly deprived of food. Yet because of the continuous small waste of protein from the tissues of the body, animals nourished solely on fats and carbohydrates cannot long survive.

93. Feeding protein alone.—We might expect that when protein only is fed to a fasting animal, in an amount corresponding to the quantity lost daily during starvation, it would replace the protein wasted from the tissues, and the animal thus be brought to nitrogen equilibrium; that is, it would excrete as much, but no more, nitrogen than was contained in the food. However, when protein is fed under such conditions, the amount of nitrogen excreted at once rises, and tho the loss of nitrogen from the tissues is reduced, nitrogen equilibrium is not reached. When practically pure protein is fed, the loss of nitrogen can be checked only if the supply is far in excess of the waste from the starving body. It is assumed that this increase in nitrogenous waste when protein is fed in such large proportion is due to a flooding of the tissues with amino acids, the products of protein digestion, and a consequent stimulation of the activities of the body cells. (**11, 49**) However, the food protein so decomposed is not entirely lost to the animal. Not only may it be burned as body fuel, thus saving the body fat, but, after the splitting of the nitrogen from the molecules of protein or of amino acids, the non-nitrogenous residue which remains may be converted into glucose and finally into glycogen or fat. Carnivora, or flesh-eating animals, have lived for long periods on washed lean meat, consisting chiefly of protein, with only a small amount of fat and a trace of glycogen. Since plant tissue is rich in carbohydrates, such experiments have not been possible with the herbivora, or plant-eating animals.

94. Protein required for maintenance.—The preceding discussions have pointed out the functions of protein in the body under various conditions. Let us now pass to a question of much practical importance—the amount of protein required to maintain animals at rest, when fed along with sufficient carbohydrates or fats to meet the needs of the body for fuel. When enough of these nitrogen-free nutrients is supplied, the amount of protein required to prevent loss of nitrogen from the body is much less than where the ration is nearly pure protein. In trials with dogs Voit[12] found that from 2.6 to 3.3 lbs. of lean meat per day was required to check the loss of protein from the body when lean meat was fed alone—practically an exclusive protein diet. When carbohydrates or fat was added, only one-half to one-third as much lean meat was needed. Since the digestible portion of the crude fiber and likewise of the pentosans can serve as body fuel (**48**), these nutrients to some degree decrease the waste of nitrogen in the same manner as does a supply of the more easily digested sugars and starch.

Experiments show that a pound of carbohydrates has somewhat greater

[12] Ztschr. Biol., 5, 1869, p. 352.

protein-sparing action than a pound of fat, a surprising fact when we remember that, on burning, fat produces over twice as much energy as do carbohydrates. (70) Evidently there is no relation between the fuel values of these nutrients and their protein-sparing power. Landegren[13] explains this superiority of carbohydrates over fat as follows: For the carrying on of their normal functions, living cells need a certain minimum not only of protein but also of carbohydrates, especially glucose. When carbohydrates are not supplied, the body forms the necessary glucose by decomposing protein. So long, however, as there is an ample supply of carbohydrates in the food, protein is not used for this purpose. As the body can form carbohydrates from fat only with great difficulty, if at all, the fats are less potent than the carbohydrates in checking the protein wastes in the body.

By feeding rations ample in carbohydrates and fat, some investigators have succeeded in reducing the requirement of nitrogenous matter to slightly more than the normal nitrogen waste of the body during starvation. At the Pennsylvania Station[14] Armsby found in experiments with steers, covering 70 days, that from 0.4 to 0.6 lb. of digestible protein daily per 1000 lbs. of live weight was sufficient to maintain the nitrogen equilibrium. Contrary to the observations of some of the earlier investigators, no ill effects followed this small supply of protein. Wintering cattle on feeds poor in crude protein—straw, inferior hay, corn stover, etc.—as practiced by many farmers, confirms this finding.

In general, it is not wise to supply only the theoretical minimum of protein to animals for extended periods for the following reasons: As we have seen (**81**, **85**), it is essential to make some allowance for the difference in composition of feeding stuffs and the varying capacities of animals to digest and utilize the nutrients in the ration. Besides supplying protein to replace the daily waste from the organs of the body, sufficient must also be given to maintain the growth of the nitrogenous hair, hoofs, wool, etc. When the ration has too wide a nutritive ratio, the digestibility of the feed is decreased. Moreover, certain proteins of unbalanced composition fed as the sole source of nitrogen will not suffice to maintain an animal. For example, in numerous experiments animals have never been maintained successfully on gelatin, which lacks 2 amino acids and contains only small amounts of others. As we have little knowledge concerning possible deficiencies in the mixture of proteins supplied in the different individual feeding stuffs, it is advisable to make allowance for waste which may occur if the feed contains low amounts of some of the amino acids essential for maintenance. It is also a well-known fact that in general protein is a cell stimulant, and a supply somewhat above the minimum promotes the well-being of the animal.

The wisdom of not attempting to limit the protein supply to the theoretical minimum for long periods is shown by the experience of Haecker[15] of the Minnesota Station. During many years of patient study he found

[13] Skand. Archiv. Physiol., 14, 1903, p. 112.
[14] Principles of Animal Nutrition, 1903, p. 142.
[15] Minn. Buls. 71, 79, 140.

that dairy cows under good care and otherwise liberal feeding would for long periods continue a good flow of milk on a surprisingly small allowance of crude protein. After some years of such feeding, however, their vitality was so depleted that they became physical wrecks long before their time. These studies led Haecker to raise his crude protein standard for the dairy cow above his earlier allowance, tho such allowance is still below the Wolff-Lehmann standard, as is shown elsewhere. (**182**)

Even when sufficient protein is fed to insure good health, the amount required to maintain mature resting animals is not large compared with the need of carbohydrates and fat for body fuel. Maintenance rations for such animals may therefore have a relatively wide nutritive ratio. For example, Kellner recommends for the maintenance of the mature ox at rest a supply of 0.6 to 0.8 lb. of digestible protein and 7.7 to 9.7 lbs. of digestible non-nitrogenous nutrients (including fat $\times$ 2.25). (**170**) Armsby places the requirement of the horse somewhat higher, as is shown later. (**172**)

95. Can amids replace proteins?—Whether the functions of protein in the body can be filled by the group of nitrogenous compounds, more simple than the true proteins, which are included under the term amids (**11**), is a disputed question among scientists. In the light of recent experiments, which have shown that even certain true proteins are insufficient for maintenance or growth when fed alone, it is not surprising that single pure amids have failed to fulfill the functions of food protein. Thus numerous experiments have shown that animals cannot be maintained on asparagin, an amid, as the sole source of nitrogen. Tho they cannot replace protein, such amids, even when fed in pure form, furnish energy to the body.

We have seen (**49**), that all the digested food protein is broken down into amino acids and absorbed as such from the intestine, being later rebuilt into body protein. With this in mind it is reasonable to hold that if the mixture of amids in a feeding stuff contains all of the amino acids (the protein building-stones) needed to form body protein, these amids can be used in the same manner as true protein for the repair of body tissue or for the formation of new protein tissue. This belief is supported by the following:

Nearly half the nitrogen in corn silage, and about 15 per ct. of that in dried corn forage, is in amid form. Yet, based on dry matter, corn silage is somewhat more valuable than corn forage as a feed for dairy cows, which require a liberal supply of crude protein. (**630**) The amids are abundant in grass, roots, and silage, all of which are especially useful to growing or pregnant animals and to those producing milk and wool.

III. Requirements for Mineral Matter

96. Importance of mineral matter.—That the ash of feeding stuffs is of the greatest importance to animals is shown by feeding them rations freed as far as possible from mineral matter, in which case they die of mineral starvation. Indeed, animals thus fed generally perish sooner than when no food is given. During such starvation the nervous system first suffers in a perceptible manner; marked weakness of the limbs, trembling of the muscles, convulsions, and great excitability result.[16]

Mineral matter is found in all the vital parts of the body. The nuclei of all cells are rich in phosphorus, and the skeleton is composed largely of calcium (lime) combined with phosphorus. Blood deprived of its calcium does not clot. The blood serum is rich in common salt and other salts of sodium, while the red blood corpuscles are rich in potassium compounds. The power of the blood to carry oxygen is due to hemoglobin, an iron-protein compound in the red corpuscles. In the stomach the pepsin acts only in the presence of an acid, normally hydrochloric, derived from the salts of this acid present in the blood.

97. Mineral salts control life processes.—In some mysterious manner, possibly by carrying electric charges which stimulate the body cells,[17] the mineral salts of the body direct its various vital processes. A simple experiment often performed in the laboratory will illustrate the important functions of the mineral elements in life. If the heart, still beating, is removed from a frog and placed in a solution of pure sodium chlorid (common salt), its beats soon fade out. Now if a small amount of a calcium salt (lime) be added to the solution, the heart will at once begin to beat again, and will continue in rhythmical contraction for several hours. Unless a small amount of a potassium salt is likewise added, the beat will not, however, be normal, the heart failing to relax quickly and completely enough after each contraction. Therefore, if potassium is not added the relaxations become more and more feeble, until the heart stops in a contracted state. Not only must potassium be present, but there must be a correct proportion between the amounts of calcium and potassium. If too much potassium is added, the heart will fail to contract properly, and finally will again stop beating, but this time in a state of complete relaxation.

Similarly, the other vital processes are dependent not only on the presence of various mineral salts, but also on a proper relationship between them. Therefore it will be seen that unless the amount of these mineral salts in the blood is kept normal, serious consequences will follow. In large measure the kidneys protect the animal against an unbalanced mineral matter content in the blood by promptly excreting any excess of various salts which may be present. However, when the food continually furnishes the blood an unbalanced salt mixture, the kidneys may be unable to keep the blood composition normal, with resultant injury to the animal. For instance, magnesium and calcium seem antagonistic in their action, and in voiding the excess of magnesium the body loses calcium. Given in excessive amount for long periods, feeds which contain much magnesium in proportion to calcium, such as wheat bran and

[16] Kellner, Ernähr. landw. Nutztiere, 1907, p. 169.

[17] Forbes, Ohio Tech. Bul. 5.

middlings are said to cause a weakening of the bones, leading to such troubles as "bran disease" or "miller's horse rickets."

Appendix Table VI sets forth the mineral constituents of representative feeding stuffs.

98. Calcium and phosphorus.—Large amounts of calcium (lime) are deposited in the bones of animals, chiefly as phosphate and in smaller amount as carbonate. Indeed, over 90 per ct. of the ash of bone is calcium and phosphorus. It is not surprising, therefore, that a long-continued lack of calcium or of phosphorus in the food is harmful to the skeleton.

Hart, McCollum, and Humphrey of the Wisconsin Station[18] have shown that the animal skeleton acts as a reserve storehouse of mineral matter, doling out calcium, phosphorus, etc., when the supply in the food is below requirements, in order that the metabolic processes of the body may be maintained. Under such conditions the calcium and phosphorus in the flesh and other soft parts remain as high as in animals liberally supplied with these mineral matters. These investigators found that a cow fed a ration deficient in calcium during 3.5 months gave off 5.5 lbs. more calcium in milk and excrement than was in the food. This was fully 25 per ct. of all the calcium in her body, including the skeleton, at the beginning of the trial.

Such withdrawal of mineral matter from the skeleton produces porosity and brittleness of bone. In certain localities where the hay and other roughages are especially low in calcium and phosphorus,[19] farm animals are so affected by the lack of these mineral substances that their bones are broken easily and in seemingly inexplicable ways. Often this brittleness of bone is noticeable only in years when the normal absorption of calcium and phosphorus by the roots of plants is hindered by drought. Of grown animals, those carrying their young are most apt to suffer from the lack of these substances, since considerable amounts are deposited in the fetus. Growing animals whose bones are rapidly increasing in size suffer from a lack of calcium or phosphorus sooner than grown animals. Voit[20] found that young animals receiving a ration low in calcium are soon attacked by rickets, the joints swelling, the limbs and the spinal column becoming crooked, the teeth remaining small and soft, and the animal finally being unable to walk. Pigs, because of restricted diet, suffer from insufficient calcium and phosphorus more often than do calves, colts, and lambs, which usually receive enough of these mineral matters in their hay and other food.

The superior value of such leguminous roughages as clover, alfalfa, and cowpea hay for farm animals has in the past been ascribed to their high content of protein. Ingle[21] holds that in such concentrates as lin-

[18] Wis. Research Bul. 5; Am. Jour. Physiol., 1909.

[19] Kellner, Ernähr. landw. Nutztiere, 1907, p. 185.

[20] Ztschr. Biol., 16, 1880, p. 70.

[21] Jour. of Comparative Pathology and Therapeutics, Mar., 1907.

seed oil cake, Indian corn, oats, wheat, and barley, and in such roots and roughages as turnips, swedes, mangels, corn stover, wheat straw, etc., there is generally an excess of phosphorus over calcium, or lime. He holds that this excess of phosphorus tends to waste or carry the calcium out of the body to an excessive degree and is therefore unfavorable to normal nutrition. The leguminous roughages contain a large excess of calcium over phosphorus, and accordingly supplying legumes with the other feeds named makes good such wastage of calcium. To this high content of calcium as well as to the high protein content we must hereafter ascribe the beneficial effects of clover, alfalfa, vetch, and other leguminous roughages on the growth, milk yield, and bone development of farm animals.

99. Mineral requirements for maintenance.—It is probable that, by reason of its perfection, the animal organism is able to use many of the mineral substances over and over for the same functions, taking them back into the circulation again after they have once been used. In spite of this frugal economy, however, losses of mineral matter from the body constantly occur, even during starvation. Ordinarily the rations of farm animals contain all the necessary mineral matters, at least in small quantities, and since the body retains them with great tenacity when the supply is meager, these small amounts usually suffice, especially for mature animals. Common salt, calcium (lime), and phosphorus are often needed in such large amounts that they may fall short in certain rations, and hence must be added, if normal results are to be obtained. As is shown later (**119**), young growing animals require larger supplies of mineral matter than those which are full-grown; hence more care should be taken to provide a liberal allowance, especially of lime and phosphorus.

In forming rations the calcium and phosphorus content of the feeds should be considered. Straw, chaff, the various root crops, molasses, and the cereals and their by-products, such as bran and middlings, are low in calcium. On the other hand, the legumes, as clover, alfalfa, etc., the meadow grasses, and many leguminous seeds, such as peas, beans, etc., are high in calcium. Straw, chaff, beet pulp, potatoes, and molasses are low in phosphorus, while the cereals and brans, malt sprouts, oil cakes, brewers' grains, slaughter-house and fish waste carry it in abundance. Both calcium and phosphorus may thus be lacking in some rations. When soft water is drunk, the calcium is especially apt to be deficient.

100. Inorganic phosphorus.—A considerable part of the phosphorus of common feeding stuffs is present in the proteins, the phosphorus-containing fatty substances, and other organic compounds. A higher nutritive value has often been ascribed by scientists to phosphorus in these compounds than to phosphorus in such materials as ground rock phosphate, ground bones, or bone ash, which contain phosphorus in inorganic form, like phosphate of calcium. These materials are the cheapest forms in which phosphorus can be added to a ration deficient in this mineral nutrient. The question as to whether animals can assimilate inorganic phosphorus and whether the body can use it for all purposes which organic phosphorus serves, are therefore questions to which scientists have devoted much study.

Köhler[22] found that lambs can assimilate and use calcium phosphate, bone ash, and steamed bone. J. Neumann[23] fed calcium carbonate and calcium phosphate to calves with good results. Experiments at Möckern[24] indicate beneficial results from the use of 30 to 50 grams of calcium phosphate in the daily ration of steers which had shown marked brittleness of bone. At the Wisconsin Station,[25] Hart, McCollum, and Fuller found that pigs were able to assimilate inorganic phosphorus supplied in the form of precipitated calcium phosphate, bone ash, or ground rock phosphate, and that the addition of such phosphorus to a ration low in phosphorus caused increased bone formation. From 5 experiments with growing pigs, in which either inorganic phosphates or phosphorus in organic forms were added to rations low in phosphorus, Forbes[26] of the Ohio Station concludes that the inorganic phosphates were absorbed and retained, and apparently utilized for growth in the same manner as the phosphorus in organic form.

We may therefore conclude that when a ration must be used which is deficient in calcium or phosphorus, calcium may be supplied in the form of calcium carbonate in wood ashes or ground limestone, or phosphorus and calcium in the form of precipitated calcium phosphate, bone ash, or ground rock phosphate. This latter is by far the cheapest form of phosphorus easily available for such purposes.

101. Common salt.—The hunger of herbivorous animals for common salt is well known, but practical men have differed as to the necessity or advantage of adding it to the ration. In spite of the earlier belief that salt increased the digestibility of food, numerous experiments have shown that the digestibility of the ration is neither increased nor diminished thereby. Rather than increasing the waste of protein from the body, as earlier investigators believed, salt appears to slightly lessen protein decomposition. Kellner[27] states that besides the physiological action of salt, it serves as a spice or condiment which whets the appetite and increases the palatability of many foods. It also stimulates the secretion of the digestive fluids, hastens the circulation of the fluids of the body, and prevents digestive disturbances.

Excessive consumption of salt must be guarded against, since it greatly increases the amount of water excreted in the urine. The consequent abnormal thirst causes animals to drink excessively, which impairs digestion and leads to other disturbances. If sufficient water is not supplied, the water content of the body will be lowered by the increased loss thru the kidneys, leading to greater waste of protein. Animals allowed free

[22] Landw. Vers. Stat., 61, 1905; 65, 1907.
[23] Jour. Land., 41, 1893, p. 343.
[24] Landw. Vers. Stat., 57, 1902, p. 239.
[25] Wis. Research Bul. 1.
[26] Ohio Tech. Bul 5.
[27] Ernähr. landw. Nutztiere, 1907, p. 173.

access to salt or supplied with it at frequent and regular intervals will consume only enough to meet the needs of the body.

Of the numerous salt-feeding experiments, only those of Babcock and Carlyle of the Wisconsin Station[28] are satisfactory and conclusive. In these trials dairy cows, well nourished otherwise, were given no common salt (sodium chlorid) for long periods—more than a year in some instances. The following conclusions were reached: "In every case the cows exhibited an abnormal appetite for salt after having been deprived of it for 2 or 3 weeks, but in no case did the health of the animal, as shown by the general appearance, the live weight, or the yield of milk, appear to be affected until a much longer time had elapsed. This period of immunity varied with individual cows from less than a month to more than a year. There was finally reached a condition of low vitality in which a sudden and complete breakdown occurred. This stage was marked by loss of appetite, a generally haggard appearance, lusterless eyes, a rough coat, and a very rapid decline in both live weight and yield of milk." If salt was supplied at this period recovery was rapid. In one case potassium chlorid was given instead of common salt (sodium chlorid). Considerable of the potassium salt was eaten, tho cows ordinarily refuse to touch it, and recovery followed as quickly as when common salt was supplied—evidence that not the lack of sodium but the lack of chlorin was responsible for the troubles. The breakdown due to the lack of salt usually occurred after calving when the milk flow was heavy, and generally the cows giving the largest amount of milk were the first to show distress.

Babcock points out that the salt requirement will vary greatly in different localities. Soils which contain large quantities of salt doubtless produce feeding stuffs containing more salt than those poor in this ingredient; and again, the water of streams and wells varies greatly in salt content. These facts doubtless account for the disagreement among experimenters in different parts of the world as to the importance and value of salt. Cows in milk and sheep show the greatest need of salt; fattening cattle, horses, dry cows, and stock cattle require less salt; and pigs but little.

IV. Additional Requirements of Animals

We have thus far considered in detail only the requirements of animals for crude protein, carbohydrates, fat, and mineral matter. However, just as vital as the demands for fuel and repair material, which are met by these nutrients, is the need for air and water. It is also necessary that the ration in its physical nature or bulkiness be adapted to the capacity of the digestive organs of the given animal.

102. Air.—While animals survive starvation for considerable periods, lack of air brings immediate death, as a supply of oxygen is required for all vital processes. The amount of air breathed by farm animals, as

[28] Wis. Rpt. 1905.

given by King,[29] is placed in the first division of the table below. The second division shows the quantity of fresh air that must pour into a room where animals are confined, in order to provide substantially pure air, or that which does not contain over 3.3 per ct. of air that has been previously breathed.

Air breathed by animals, and air required for good ventilation

Animal	Air breathed			Ventilation requirement per animal	
	Hourly	Per 24 hrs.		Hourly	Per 24 hrs.
	Cu. ft.	Cu. ft.	Lbs.	Cu. ft.	Cu. ft.
Horse	142	3,401	272	4,296	103,104
Cow	117	2,804	224	3,542	85,008
Pig	46	1,103	89	1,392	33,408
Sheep	30	726	58	917	22,008

The table shows that the horse breathes hourly 142 cu. ft. of air, and daily about 3,400 cu. ft., which weighs about 272 lbs. To provide the horse in confinement with air, not more than 3.3 per ct. of which has been previously breathed, there must hourly pass into the room not less than 4,296 cu. ft., or over 103,000 cu. ft. each 24 hours. These figures show the necessity of providing some adequate system of ventilation when animals are confined to closed barns, as in the case of horses and dairy cattle during winter in the northern states.

The cow gives off about 19 therms of heat each 24 hours, or enough to raise 79,603 cu. ft. of dry air from 0° to 50° F. As shown in the preceding table, proper ventilation for the cow requires about 85,000 cu. ft. of air each 24 hours. This is only a little more air than the heat from her body will raise from 0° to 50° F., which is a desirable winter temperature for cow stables in cold climates.

103. Water.—Animals can live much longer without solid food than without water, and an insufficiency of water in the body causes serious disturbances. The processes of mastication, digestion, absorption, and assimilation are hindered; the intestines are not properly flushed, and waste matter remains too long therein; the blood thickens; and the body temperature is increased. Thru these complications death may result. Animals partially deprived of water for a long period lose their appetite for solid food, and vomiting and diarrhea may occur, the latter also often taking place when water is again supplied.

Under normal conditions animals consume a fairly uniform quantity of water for each pound of dry matter eaten; Kellner places the amount at 4 to 6 lbs. for milch cows, 4 to 5 lbs. for oxen, 2 to 3 lbs. for horses and sheep, and for swine 7 to 8 lbs., which seems excessive. Possibly due to their laxative nature, feeds rich in crude protein—bran, linseed meal, peas, etc.—cause a greater demand for water than starchy feeds.

[29] Ventilation for Dwellings, Rural Schools, and Stables.

Kellner[30] found that for each 100 lbs. of water drank and in the food, the stabled ox passed 46.3 lbs. in the solid excrement, 29.2 in the urine, and 24.5 in the breath and perspiration. Water is an important regulator of the temperature of the animal body. A large amount of heat is absorbed in converting water into the vapor given off by the lungs and skin, and when sweat evaporates it carries much heat from the body. (90)

The free drinking of water does not diminish the gains of animals nor increase the breaking down of protein in the body, tho flushing the intestines with much water may at first cause a more complete removal of the nitrogenous waste therefrom. With animals which continue to drink freely the nitrogenous waste soon becomes normal again. Scientists now agree that farm animals should have all the water they will drink, for they do not take it in excess unless they are forced to live on watery foods or are given salt irregularly. The excess of water taken into the body is discharged thru the urine.

Water taken into the body must be raised to the body temperature, thus consuming heat. When an undue amount of cold water is drunk in cold weather this demand for fuel may cause a waste of nutrients. Warington[31] points out that during winter sheep in the turnip fields of England consume about 20 lbs. of roots daily, containing over 18 lbs. of water, or about 15 lbs. more than is needed. To raise 15 lbs. of water from near the freezing point to the body temperature requires the burning of 11 per ct. of the nutrients furnished by the turnips. In addition the equivalent of more than 2 oz. of glucose must be burned for each pound of water vapor given off from the lungs and skin. Warming cold water taken into the body does not necessarily mean that more food must be burned, for animals evolve a large amount of heat in the work of digesting food and converting the digested matter into body products or work. Due to this, many animals have an excess of body heat. Comfortably-housed and well-fed steers and dairy cows burn more food than is needed to keep their bodies warm, and such excess may go to warm the water they drink, so that no food is directly burned for that purpose.

Armsby[32] points out that in winter farm animals watered but once daily drink freely. The sudden demand for heat caused by taking into the body this large quantity of cold water may exceed the available supply, with the result that some of the food nutrients or body tissues are burned to produce heat. Animals unduly exposed to cold and those sparingly fed or with scant coats may be directly helped by watering frequently or by warming their drinking water. In cold regions in order to induce animals, especially cows, to drink freely in winter, it is usually best to warm the water, which should also be comfortably accessible.

When entirely oxidized in the body, 100 lbs. of starch or cellulose will yield 55.5 lbs. of water and 163 lbs. of carbon dioxid, and fats over

[30] Landw. Vers. Stat., 53, 1900, p. 404. [32] Principles of Animal Nutrition, p. 439.
[31] Chemistry of the Farm.

twice as much water as starch. The nitrogenous compounds yield a little less than the carbohydrates because they are not entirely oxidized in the body. This shows that a very considerable amount of water comes to the animal body from the dry matter of the food consumed. It is probable that the water which results from the breaking down of the food is used in the building processes of the body, rather than that water which the animal drinks, tho this is not definitely known.

104. Commonly unappreciated factors in food.—Within recent years evidence has been accumulating which indicates that the classes of nutrients previously enumerated—proteins, carbohydrates, fats, and inorganic salts—are not all that is necessary to make a satisfactory ration. It has long been known that when humans live for extended periods on a diet containing no fresh vegetables or meat, scurvy is apt to result, even tho an abundance of the common nutrients is furnished. The addition to the diet of fresh vegetables readily prevents this disease. In districts of the Orient, where the inhabitants subsist mainly on polished rice, there often occurs a serious disease known as beri-beri, characterized by general weakness and even paralysis. Where unpolished rice, carrying the germ and part of the husk, is eaten instead, this disease is not found. In experiments by various scientists a similar condition has been produced in animals fed almost exclusively on polished rice, while unpolished rice did not cause such an effect. Tho many attempts have been made to determine the mysterious substance in the rice husk or germ which exerts such a pronounced influence on health, but little is yet known regarding its composition.

Another important development of recent years has been the finding that some of the substances included in the ether-extract or so-called "fat" of feeds are essential to the well-being of animals. Stepp[33] first found that animals well fed upon foods from which all substances of a fatty nature had been removed could not live. He further found that no better results were secured when pure true fats, such as palmatin, stearin, and olein—the most common plant and animal fats—were added to the ration. On the other hand, when certain crude fatty extracts of foods, such as butter fat, were added, the animals could be maintained in a satisfactory condition. McCollum and Davis[34] of the Wisconsin Station subsequently showed that young animals (rats) could grow normally for 3 or 4 months on mixtures of casein, starch, milk sugar, and salts, but that growth then invariably ceased. The addition of lard, olive oil, or cottonseed oil did not prevent this condition. However, the addition of purified butter fat, egg fats, or kidney fat rendered the diet complete in every respect. Young rats grew from infancy to maturity, bore young, and brought them up normally on this ration. More recently they have shown that the fats of the corn kernel and the wheat germ likewise supply the lacking constituent in the ration. These findings have been

[33] Biochem. Ztschr., 22, 1909, pp. 452–460; Ztschr. Biol., 59, 1912, p. 366.

[34] Jour. Biol. Chem., 15, 1913, p. 167; 19, 1914, p. 245; 20, 1915, p. 641; 21, 1915, p. 179.

confirmed by Osborne and Mendel[35] of the Connecticut (New Haven) Station, who have found also that cod-liver oil and the softer portion of beef fats have the same remarkable properties.

The foregoing experiments have shown for the first time a most unexpected and important difference in the properties of the so-called fats from different sources. It seems certain that the substances which are responsible for the peculiar effects of these crude fatty mixtures are not true fats, but compounds of unknown nature which are soluble in fats and in the ether which is employed by the chemist to dissolve the fat from a feed.

105. Complete and incomplete rations.—The following experiments conducted by Hart and McCollum[36] at the Wisconsin Station with growing pigs well show that rations which supply an abundance of protein, carbohydrates, and fat may be insufficient for normal development. Soon after weaning, young pigs were placed in pens indoors where they had no access to the earth and were supplied with distilled water (containing no mineral matter), so that an exact record could be made, not only of the organic nutrients—protein, carbohydrates, and fat—which were consumed, but also of the mineral matter as well. When pigs were restricted to corn meal and gluten feed, even tho a large amount of protein was supplied, little or no growth could be secured. However, when mineral matter was added, of kind and amount corresponding to the mineral matter in milk, pigs made approximately normal gains for 10 months, reaching weights of 235 to 275 lbs. When wheat and wheat gluten were fed, satisfactory growth was not secured even after mineral matter was added as before. The addition of both butter fat and mineral matter was somewhat beneficial, but ultimately growth ceased on this ration. However, when to the wheat ration were added not only butter fat and mineral matter but also 2.5 per ct. of casein (the chief protein of milk) normal growth was secured. These pigs fed wheat therefore needed not only additional mineral matter but also the mysterious substance in certain fats, and in addition a better balanced supply of protein than was furnished by wheat and wheat gluten alone.

Studies of this character are just beginning to open up new fields of investigation in animal nutrition. It is yet too early to predict in what manner or to what extent the results may modify our present practices in feeding farm animals. These fragments of knowledge are, however, most interesting to the student in showing the limitations to our present understanding of the feeding of animals and in pointing out the possible path of future development.

106. Feeding ruminants concentrates only.—By reason of their high ability to digest coarse roughage, ruminants are especially adapted to convert the coarse plant materials of no value for human food into useful

[35] Jour. Biol. Chem., 16, 1913–14, p. 423; 17, 1914, p. 401; Proc. Soc. Exper. Biol. and Med., 12, 1915, p. 92.

[36] Jour. Biol. Chem., 19, 1914, p. 373.

products. Tho only under most exceptional conditions would it be profitable to feed such animals concentrates alone, the question whether they can be maintained on such feeds with no roughage is of scientific interest.

In 1874 a Mr. Miller[37] of New York reported that for several years he had successfully maintained dry dairy cows weighing about 900 lbs. for 8 weeks in winter by giving to each animal as its sole feed not above 3 quarts of finely-ground corn meal daily. The hay supply was stopped when meal feeding began. At first the cows were restless, but soon quieted down; rumination, or chewing the cud, ceased; and only a small quantity of water was drunk. The cows showed no signs of suffering or unrest, were much more quiet than cows fed meal with 4 or 5 lbs. of hay daily, and manifested no unusual desire for hay when it was shown them.

Miller claimed that the animals remained in fair flesh and that the calves from these cows were fleshy, healthy, active, and of more than ordinary size. In the spring on changing back to normal feeding a limited amount of hay was at first given, and the supply gradually increased. The cows soon filled up and did not appear different from others wintered in the usual way. A committee of the American Dairyman's Association, on making 2 visits to Mr. Miller's stables, substantiated his statements.

Sanborn[38] maintained sheep successfully for several months on grain and roots alone at the Utah Station. In Great Britain sheep are often fattened solely on concentrates and roots. Sanborn also fed a 2-yr.-old steer, weighing 635 lbs., grain and water only for nearly 8 months, during which time it gained 190 lbs. Upon the withdrawal of coarse food, rumination ceased and little water was drunk. Gains were made on about the same amount of feed as is required by pigs. We may therefore conclude that mature ruminants can be maintained for considerable periods, if not indefinitely, on a limited amount of ground grain with no roughage, and if the grain supply is liberal they may make fair gains in weight.

With young ruminants nature seems less yielding. Sanborn maintained a calf for 6 weeks in winter on grain and milk, when, thru its craving for roughage, the sawdust used for bedding was eaten, causing death. At the Illinois Station Davenport[39] fed a calf skim milk exclusively for 7 months, by which time it refused its feed, could not hold up its head, and appeared nearly dead. When straw and hay were placed before it they were greedily consumed, and 3 hours later the calf was ruminating in contentment, thereafter making satisfactory gains on mixed feed. In a second experiment a May calf subsisted on skim milk until September, when, altho consuming 70 lbs. daily, it showed great unrest. Some grain was then fed in addition to the milk, with still unfavorable indications. In October when hay was offered it was greedily eaten, and rumination began some five hours later. Another calf was

[37] Rpt. Am. Dairyman's Assoc., 1874. [38] Utah Bul. 21. [39] Ill. Bul. 46.

maintained from June until September upon milk and mixed grains. By the latter date it evinced no desire for feed and would not rise; later it suddenly died. Altho enormous quantities of milk or milk and grain were consumed, there was no fat on the carcass or about its kidneys, and the muscles, tho plump, were dense and rigid.

107. Horse requires roughage.—Patterson of the Maryland Station[40] attempted to feed 2 horses on oats alone, offering from 13 to 15 lbs. to each daily. By the end of the fourth day one of the horses refused the oats entirely and drank but little water. On the seventh day the other horse would eat only a part of the grain, and by the tenth day none whatever. Evidently the horse cannot live upon concentrates alone, even oats with their straw-like hulls.

108. Milk alone for pigs.—At the Wisconsin Station[41] McCollum placed a 23-lb. sow pig in a dry lot with shelter, and fed it from May to July of the following year, at first on whole milk and skim milk, and later on skim milk alone. The sow remained in excellent condition, and at about 1 year of age, when weighing 406 lbs., gave birth to 8 living pigs averaging 2.3 lbs. each, and 2 dead ones, all normal. Before winter the pigs made an average daily gain of 0.39 lb. each, reaching an average weight of 18.6 lbs. in 6 weeks.

This shows that milk alone will support the pig, and indicates that the failure of Davenport to maintain calves on skim milk and grain was probably due to the physiological requirement of herbivora for coarse food to fill the first three stomachs in order that they may develop normally. (**40**) The pig has no such peculiarity in the structure of its digestive tract, and hence no physiological disturbances result from taking liquid food alone in the form of milk.

109. Succulent feeds.—Numerous scientific trials and common experience on farms have abundantly demonstrated the value of adding succulent feeds to the rations of farm animals. The beneficial effects of succulence, whether supplied as pasturage, silage, soilage, or roots, are many. Just as our own appetites are stimulated by fruits and green vegetables, succulent feeds are relishes for the animals of the farm, inducing them to consume more feed and convert it into useful products. It is reasonable to hold that such palatable feeds stimulate digestion (**56**), and it is well known that their beneficial laxative action aids greatly in keeping the digestive tract in good condition. The findings of Sanborn[42] that the flesh of root-fed animals is in general more "sappy" or watery has an important bearing on the feeding of farm animals. There is no doubt that, for breeding stock, less tense and more watery flesh, a natural sequence of feeding succulence, is more conducive to vigorous young at birth and to their hearty maintenance after birth than is the condition of hard, dry flesh produced by feeding only dry forage thru the winter. The dairy cow gives her maximum returns when she is supplied with succulence. Such feeds tend toward rapid, sturdy growth

[40] Md. Bul. 51. [41] Unpublished data. [42] Utah Bul. 17.

with the young of all farm animals. Some succulent food is especially beneficial in keeping the horse in condition, to which the thrift of the work horse when turned out to pasture bears witness. But the horse at hard or fast work should receive only a limited allowance of these feeds. Steers and sheep make rapid and economical gains on pasture, and grass-fed animals are in the best possible condition to make rapid gains when placed in the feed lot. Among the most important contributions of the experiment stations are their demonstrations of the economy of feeding silage to fattening cattle and sheep and of the possibilities of cheapening the cost of producing pork thru the utilization of pasture. The merits of the various forms of succulence for the different farm animals are discussed in detail in later chapters of the book.

110. Light.—Sunlight is a most effective germicide. To prevent the contraction or spread of disease, it is therefore important that the stables of farm animals be well lighted, with the possible exception mentioned in the following. Trials conducted by Graffenberger[43] with rabbits suggest that less light may be advisable for fattening animals fed for short periods. He observed an increased formation of fat, especially marked in the case of mature animals confined in a dark room. The hemoglobin content of the blood was lowered and the amount of blood in the body decreased by 9 to 22 per ct. thru such confinement. When confined too long in the dark the increase in fat formation was relatively small, and prolonged darkness retarded the development of the skeleton and liver, injuring the health of the animals. Graffenberger does not advocate entire darkness for fattening animals, but rather the partial absence of light, which tends to quiet and hence favors fattening.

111. Exercise.—For the maintenance of health exercise is essential. The only exceptions to this rule are fattening animals, soon to be marketed, which make more rapid gains if not allowed to move about too freely. Abundant exercise is of special importance with breeding animals. The exercise requirements of the various farm animals are discussed in the respective chapters of Part III.

112. Quiet and regularity.—Farm animals are creatures of habit, and once accustomed to a routine of living show unrest at any change. The feed stable or feed lot should be free from disturbance, and the administration of feed and water should be uniform in time and manner. Animals soon learn when these are to occur, and as feeding time approaches the secretions begin pouring from the various digestive glands in anticipation of the coming meal. (**55**) The system of feeding and watering and the character of the rations should be changed gradually and only for good cause. In feeding operations a changing period is usually a losing period.

[43] Arch. Physiol. (Pflüger), 53, 1893, p. 238.

CHAPTER V

GROWTH AND FATTENING

I. Growth

The preceding chapter shows that even when liberally fed the mature animal stores but little protein or mineral matter in its body. On the other hand, as the body of the young, growing animal develops it increases rapidly in both protein tissues and mineral matter. The skin, muscles, ligaments, tendons, and internal organs of animals are almost wholly protein, as is a large part of the nervous system and of the organic portion of the bones. During youth all these parts steadily increase in size, and at the same time much mineral matter is being built into the skeleton or is retained in the growing protoplasm of the body cells. It is therefore evident that the requirements for growth differ radically from those for the maintenance of mature animals.

113. Increase in protein and mineral matter.—Since the lean-meat tissues of the body are composed mostly of muscular fibers, any gain in these tissues can be caused solely by an increase in the number or by the thickening of these fibers. The fibers increase in number by dividing lengthwise, which process occurs with farm animals only while young and growing. Indeed, recent investigations show that with some animals all increase in the number of muscular fibers occurs before birth, the muscles of the new born young containing as many as those of the mature animal.[1] The fibers of the muscles can thicken to only a limited extent, and hence the muscular tissues, or lean meat, of the mature animal cannot be increased beyond a relatively narrow limit, compared with the great storage of fat which may occur.

A healthy person with poor muscular development may materially strengthen and increase the size of his muscles, even after reaching maturity, thru a thickening of the individual fibers produced by suitable exercise and food. Caspari,[2] studying working dogs, and Bornstein,[3] experimenting with himself, found that when a considerable amount of muscular work was performed there was a small but continued gain of body protein if the body was supplied with an abundance of protein-rich food. An animal whose muscles have wasted thru sickness or starvation will rapidly repair its tissues upon a return to favorable conditions, thereby storing protein.

Since the internal organs and such tissues as the tendons, brain, nerves, etc., do not increase in size after maturity, no further building of protein

[1] J. B. MacCallum, Johns Hopkins Hospital Bul. 90-91 (1898).

[2] Archiv. Physiol., 83, 1901, p. 535. [3] Archiv. Physiol., 83, 1901, p. 548.

tissue is possible in these parts after the animal is full grown. As is shown later (**122**), a limited storage of protein occurs in the mature fattening animal, since fatty tissue contains a small amount of protein.

The skeleton, partly of protein, but chiefly of mineral matter, does not increase after maturity. While the amount of protein and mineral matter in the bodies of mature animals is thus subject to little change, the water, and especially the fat, may vary widely in total and relative amount according to heredity, the abundance and nature of the food, and the exercise taken.

114. Utilization of food in youth.—The gains made by well nourished young animals are relatively much greater and more economical, based on weight and food consumed, than those of mature animals, even when fattening. The unweaned calf may increase 2 to 3 lbs. daily for each 100 lbs. of body weight, while a daily gain of 0.3 to 0.4 lb. per 100 lbs. of body weight is large for the mature fattening ox. The economy with which the suckling utilizes its food is shown by a trial at the Wisconsin Station[4] in which lambs fed cow's milk gained 1 lb. in weight for each 0.75 lb. of dry matter consumed. In respiration studies with a calf 2 to 3 weeks old, Soxhlet[5] found a storage in the body of 72.6 per ct. of the protein, 96.6 per ct. of the lime, and 72.6 per ct. of the phosphorus fed in the milk. Weiske[6] found that even when 5 months old lambs stored 22 per ct. of all the protein digested from their food.

The more rapid increase of young animals is due to several causes—their flesh contains more water, their food is more digestible and concentrated, and they consume more food in proportion to live weight. As growth continues, the total quantity of food eaten increases, while the amount per 1000 lbs. live weight diminishes. More exercise is taken as the animal becomes older, and hence a larger percentage of the food nutrients is broken down in the body. All these factors gradually decrease the daily gain per 1000 lbs. of live weight and lessen the product returned from a given amount of food until, when maturity is reached, there is little further gain, except from the laying on of fatty tissue.

The following table by Armsby[7] shows the gain of protein, mostly muscular tissues, by the growing ox at various ages:

Storage of protein by the growing ox

Average age of animal	Authority	Daily gain of protein to the body	
		Per 1000 lbs. of live weight	Computed on total protein in body
Days		Lbs.	Per ct.
8	Soxhlet	3.99	2.35
15	Soxhlet	3.55	2.08
32	Soxhlet	2.76	1.69
50	Neumann	1.84	1.08
100	De Vries	1.19	0.71
840	Jordan	0.09	0.06

[4] Agr. Science, 6, p. 397. [5] Ber. landw. chem. Vers. Stat. Wien, 1878, p. 101.
[6] Landw. Jahrb., 9, 1880, p. 205. [7] U. S. Dept. Agr., Bur. Anim. Ind., Bul. 108.

The table shows that when 8 days old a calf stored daily in its body tissues protein equal to 2.35 per ct. of the total protein then in its body. or about 4 lbs. daily per 1000 lbs. of live weight. The storage of protein, which practically measures the growth of muscular tissues in the body, steadily decreased with age and growth until the 100-day-old calf stored 1.19 lbs., or less than one-third as much as the 8-day-old calf. When 28 months old and nearly mature, the steer stored but 0.09 lb. of protein daily per 1000 lbs. of body weight. It is thus shown that, as the animal matures, the quantity of protein built up in the body steadily diminishes.

115. Milk the natural food for young mammals.—Since milk is Nature's food for the young of all mammals, it is reasonable to hold that it contains all the nutrients necessary to sustain the life of the young and that these are arranged in proper proportion. A study of the composition of milk will therefore aid in showing the requirements for growth. The first milk yielded by the mother for her young, called *colostrum,* is thick and viscous and differs from ordinary milk in being richer in protein and often richer in ash, the colostrum of the cow being low in milk sugar. The following table shows the average composition of colostrum and normal milk of various farm animals:[8]

Composition of colostrum and normal milk

Animal and character of milk	Water	Protein	Fat	Sugar	Ash	Nutritive ratio
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Cow, colostrum......	75.1	17.2	4.0	2.3	1.5	1:0.7
Cow, normal.........	87.3	3.4	3.7	4.9	0.7	1:3.9
Ewe, colostrum......	61.8	17.1	16.1	3.5	1:0	1:2.3
Ewe, normal.........	80.8	6.5	6.9	4.9	0.9	1:3.1
Sow, colostrum.......	70.1	15.6	9.5	3.8	0.9	1:1.6
Sow, normal.........	84.1	7.2	4.6	3.1	1.1	1:2.0

The high protein content of colostrum is largely due to its excess of albumin, which causes such milk to clot on heating. Colostrum is laxative and highly important for cleansing the alimentary tract of accumulated fecal matter and properly starting the work of digestion. During the week following birth the composition of the milk gradually changes to the normal.

Normal milk contains an abundant supply of protein compared with the cereal grains, as is shown by its narrow nutritive ratio, ranging from 1:2.0 with the sow to 1:3.9 with the cow. The proportion of ash, or mineral matter, is also higher in milk than in the grains. While only 1.5 per ct. of the dry matter of corn and 3.5 per ct. of that of oats is mineral matter, 6.2 per ct. of the dry matter of cow's milk is mineral matter. The supply of lime and phosphoric acid, needed in large amounts in the growing skeleton, is especially liberal, over half the total mineral matter consisting of these two constituents. The non-nitrogenous nu-

[8] König. Chem. Nahrungs- und Genussmittel, Vol. I, 1903.

trients—milk sugar and milk fat—serve as body fuel and furnish material for the development of fatty tissues.

116. Relation between composition of milk and rate of growth.—In their analyses of different kinds of milk Bunge, Proescher, and Abderhalden[9] noted the striking relationship, shown in the table, between the rate at which different species of animals grow and the amount of mineral matter and protein contained in the milk:

Influence on growth of amount of protein and mineral matter in milk

Species	Time required to double weight Days	Protein in milk Per ct.	Lime in milk Per ct.	Phosphoric acid in milk Per ct.	Total ash in milk Per ct.
Human	180	1.6	0.03	0.05	0.20
Horse	60	2.0	0.12	0.13	0.40
Cow	47	3.5	0.16	0.20	0.70
Sheep	15	4.9	0.25	0.29	0.84
Pig	14*	5.2	0.25	0.31	0.80
Dog	9	7.4	0.45	0.51	1.33
Rabbit	6	14.4	0.89	0.99	2.50

* According to more recent data the young pig may double its weight in 9 to 10 days.

The infant, which requires about 180 days to double its weight, receives a milk containing but 1.6 per ct. protein, 0.03 per ct. lime, 0.05 per ct. phosphoric acid, and 0.20 per ct. total ash, or mineral matter. The shorter the time required by the new-born young of different species to double in weight the higher is the protein and mineral content of the milk, especially in lime and phosphoric acid. It thus appears that there has been provided for the young of each species milk of the composition needed for the development characteristic of that species. These studies emphasize the necessity of maintaining a liberal supply of protein and mineral matter in the ration of young animals as the mother's milk is replaced by other feeds during their early life.

117. Rich and poor milk for young animals.—Beach of the Connecticut (Storrs) Station[10] fed calves, pigs, and lambs on skimmed milk, ordinary milk containing from 3 to 3.5 per ct. fat, and rich milk containing from 5.1 to 5.7 per ct. of fat. The lambs also received a small quantity of hay. The table shows the milk solids, including fat, required to produce 1 lb. of gain:

Milk solids consumed per 1 lb. gain by calves, pigs, and lambs

Length of feeding period	Skim milk Lbs.	Milk poor in fat Lbs.	Milk rich in fat Lbs.
Calves fed 45 days	....	1.03	1.18
Pigs fed 40 days (1st trial)	....	1.36	1.78
Pigs fed 30 days (2nd trial)	1.48	1.40	1.56
Lambs fed 60 days	....	1.08*	1.37*

* 0.42 lb. digestible matter in hay, additional.

In every case milk rich in fat was less valuable per pound of dry matter, fat included, than milk poor in fat, or even skim milk. Beach reports that the pigs fed rich milk suffered loss of appetite and were attacked by diarrhea, finally not eating enough to sustain life, while those fed

[9] Abderhalden, Ztschr. physiol. Chem., 27, 1899, p. 594.

[10] Conn. (Storrs) Bul. 31.

skim milk or milk low in fat, throve. The lambs on rich milk showed lack of appetite.

In Europe studies on infant feeding show that cow's milk rich in fat tends to produce intestinal disturbances and is not so well adapted to the needs of the human infant as poorer milk. The following explanation of this harmful effect of excess of fat in the food of infants has been offered: The general capacity of an organism for the absorption of fat is strictly confined within narrow limits, and consequently any excess is not absorbed but remains in the intestines. There it is converted into soaps, composed of part of the fats and an alkali, and as such eliminated from the body in the excreta. This excretion of soap brings about a heavy loss from the infant body of alkaline bases, such as soda, potash, lime, etc., which, if continued, results in disturbed nutrition. On an exclusive diet of milk containing about 3.5 per ct. fat, the supply of alkaline bases is only sufficient for normal development. Milk rich in fat does not contain proportionally more of the alkaline bases, for man has bred and selected cows only to meet the demands for more milk and for that which is rich in fat. As Kellner[11] suggests, the eagerness with which calves eat mortar, chalk, and other lime-containing substances points to the milk being deficient in this respect; accordingly in such cases it is advisable to supply calves with chalk or ground limestone.

118. Protein requirements for growth.—As has been shown (**11**), the individual proteins differ markedly in the amount of the various amino acids they contain, and in some proteins certain amino acids are entirely absent. Scientists believe that animals are not able to construct in their bodies from other nutrients any of the different amino acids, with the single exception of the amino acid called glycocoll. In the formation of the protein tissues of the body all the various individual amino acids are required, for the body proteins contain some of each of these building stones. Hence for normal growth the protein in the food must supply all of the necessary amino acids. The following illustration will show the conditions the body may meet in forming body proteins from the mixture of amino acids resulting from the digestion of the food protein: Suppose we are building a brick wall in a certain pattern which requires that 1 brick in 10 have a green end. If we are using as our source of material a pile of bricks resulting from the tearing down of another wall, in which only 1 brick in 50 had a green end, it is evident that we would soon have to stop building, tho having many perfect bricks left, because none had the green end required for the pattern.

Some proteins, as the principal ones of wheat, yield on digestion as much as 40 per ct. of a certain single amino acid, which forms only 14 per ct. of the animal proteins. With this protein as the sole source of amino acids for growth, obviously a considerable part will be wasted. There are other proteins which entirely lack some of the essential amino acids and so will produce no growth. However, when the missing amino

[11] Ernähr. landw. Nutztiere, 1907, p. 461.

acids are fed to supplement such a deficient or imperfect protein, the animal will then be able to continue growth.[12]

The various incomplete proteins do not all lack the same amino acid. Hence we should expect that when 2 incomplete proteins were combined, the first might supplement the deficiencies of the second and better growth be made than on either alone. To study this problem McCollum[13] has recently fed 60 to 75-lb. pigs on many rations in which a single feeding stuff or 2 or more feeds, mixed in various proportions, supplied the protein. The percentage of the food nitrogen which was retained for growth on each ration was determined with the results shown in the table:

Value for growth of protein from various sources

Source of protein	Number of trials	Proportion of nitrogen in food retained Per ct.
Skim milk	1	66.2
Casein	1	50.6
Corn	4	23.7
Wheat	3	26.7
Oats	2	28.3
Linseed meal	1	17.0
Wheat embryo	1	39.0
Corn 1/3, wheat 1/3, oats 1/3	1	32.0
Corn 3/5, linseed meal 2/5	1	32.0
Corn 3/4, linseed meal 1/4	1	37.0
Wheat 1/2, wheat embryo 1/2	1	30.0

The milk proteins, which resemble the body proteins in composition more than do those of the cereals, were much superior to corn, wheat, or oat protein for growth, 66.2 per ct. of the protein of skim milk being used for growth. In the single trial reported a mixture of one-third of each of these cereals proved slightly superior to any single one. While linseed meal fed as the sole source of protein was the least efficient of any of the feeds tested, when it was combined with corn the results were considerably better than with corn alone. From this we may assume that linseed meal and corn are not deficient in the same amino acids, and that when combined one tends to correct the deficiencies of the other. This agrees with the good results secured in numerous scientific trials and in practice when linseed meal is fed as a supplement to corn. On the other hand, no better results were secured when wheat and wheat embryo were combined than the average of the results obtained when each was fed separately. In this case evidently each feed is deficient in the same amino acids, and one cannot supplement the other. In time further studies of this character will, no doubt, reveal the supplementary relationships of the many feeding stuffs and so make possible the more efficient compounding of rations. From the foregoing it is evident that not only must the supply of protein for growing animals be liberal but its composition should also be considered.

[12] Osborne and Mendel, Jour. Biol. Chem., 17, 1914, p. 325.

[13] Jour. Biol. Chem., 19, 1914, p. 323; information to the authors.

The methods of determining the amounts of the individual amino acids furnished by different feeds are not sufficiently perfected as yet to enable scientists to ascertain by chemical analysis alone the value of the proteins from various sources. Hence, further knowledge concerning the value of the proteins furnished by individual feeding stuffs and by combinations of feeds must come thru actual feeding tests. The available data on the protein requirements for growth by the various farm animals and the nutritive values of the different feeding stuffs are presented in the respective chapters of Part III.

119. Mineral matter required for growth.—It has already been shown that the young animal, growing rapidly in skeleton and tissues, needs a liberal supply of mineral matter, especially calcium (lime) and phosphorus. (**113**) The amounts supplied in the feeds must always be larger than the quantity actually stored in the body, in order to cover the continuous excretion thereof from the body which occurs even in case of a deficient supply.

The effects of a lack of mineral matter are shown in a trial by Hart, McCollum, and Fuller[14] at the Wisconsin Station in which one lot of pigs averaging 47 lbs. in weight was fed a ration consisting of wheat bran from which a large amount of phosphorus, mostly in organic form, had been removed by washing, and wheat gluten and rice, both extremely poor in mineral matter. As shown in the table, other lots were fed this basal ration plus calcium phosphate, bone ash, and ground rock phosphate, respectively, all supplying inorganic phosphorus. A fifth lot was fed unwashed wheat bran, rice, and wheat gluten, a ration in which a considerable part of the phosphorus was present in organic form.

For a considerable period all the pigs throve fairly well, tho no ration was entirely satisfactory. As time went on, those in Lot I fell behind the others; they had no appetite and remained lying down; later they lost control of their hind quarters and had to be carried to the trough at feeding time. At the end of 4 months, when a pig of each lot was slaughtered, the findings given below were obtained:

Scant and full allowance of organic and inorganic phosphorus for pigs

	Lot I No phosphorus added	Lot II Precip. calc. phosphate added	Lot III Bone ash added	Lot IV Ground rock phosphate added	Lot V Unwashed wheat bran
Av. amt. phosphorus fed daily, grams	1.12	5.29	5.45	5.20	5.28
Weight of pig at slaughter, lbs.	77	87	85	82	87
Average gain per pig, lbs.	32	42	35	43	58
Weight of skeleton, grams	870	950	950	1495	850
Breaking strength of thigh bone, per sq. millimeter, lbs.	0.87	1.70	1.77	1.65	1.86
Diam. of thigh bones, millimeters	16	16	15.5	20	17
Specific gravity of thigh bone	0.98	1.15	1.12	1.19	1.14
Ash in thigh bone, per cent	33	46	53	57	54

[14] Wis. Res. Bul. 1.

The pigs of the first lot, getting little phosphorus, had light, weak thigh bones, of low specific gravity and low in ash. The ones getting a liberal supply of inorganic phosphorus, especially those fed ground rock phosphate, had heavier skeletons than either the low-phosphate lot or even those getting organic phosphate in the unwashed bran. The thigh bones of the rock-phosphate lot were the largest in size and the highest in ash and specific gravity. At present there is little data regarding the minimum amounts of lime and phosphorus which will permit normal development of growing animals. From the available data Kellner[15] concludes that the ration for growing animals should contain 3 times as much of these mineral constituents as the animals are storing daily in their bodies. On this basis he recommends that during the first year calves receive at least 40 to 60 grams of lime and phosphoric acid per head daily; pigs, 12 grams each of lime and phosphoric acid per head daily; and lambs, at least 10 grams of lime and 11 grams of phosphoric acid daily for each 100 lbs. live weight.

Since the common feeding stuffs which are rich in protein are likewise high in phosphorus, probably the phosphorus supply will be ample when rations are fed which are balanced according to the usual feeding standards.[16] The calcium supply for calves and lambs will usually be ample when hay and the cereals constitute the greater part of the ration. Deficiencies will occur only in districts where the roughages are unusually low in lime, or when large amounts of such roughages as wheat and barley straw or timothy hay, which are low in lime, are fed. Where pigs are fed exclusively on cereal grains, especially on corn, the lime supply will usually be deficient. As has been shown (**99–100**), where lime alone is deficient it may be supplied in legume hay, which is rich in lime, or in the form of chalk or ground limestone. If phosphorus alone, or both lime and phosphorus are lacking, these may be supplied in ground rock phosphate or else in the form of bone ash.

120. Requirements for pregnant animals.—In considering the feeding of young animals it is important to remember that the influence of the feeder begins before the young are born, for the nutrition of the mother during pregnancy profoundly influences the growth of the fetus and hence the vigor and health of the offspring at birth. To supply the protein and mineral matter, especially lime and phosphorus, needed for the development of the body tissues and skeleton of the fetus the ration of the mother should contain a larger supply of nutrients than would be required for her maintenance. Based on data from Eckles and P. F. Trowbridge[17] of the Missouri Station, the body of an 80-lb. new-born calf contains about 14.0 lbs. of protein, 2.8 lbs. mineral matter, and 2.5 lbs. fat,—an amount of protein and mineral matter that would be contained in 400 lbs. of milk of average composition.

[15] Ernähr. landw. Nutztiere, 1907, pp. 472, 476, 478.

[16] Hart, Steenbock, and Fuller, Wis. Res. Bul. 30.

[17] Information to the authors.

In the case of an immature female, still developing her own tissues as well as those of the fetus, a liberal supply of these nutrients is especially important. Fortunately the mother is able to protect the offspring to a certain extent against temporary or small deficiencies in her food by drawing upon her own skeleton for the lime and phosphorus and her muscular tissues for the protein necessary to the growing body of the fetus. Such maternal protection is, however, at the expense of her own body. The requirements for the various farm animals when pregnant and the feeds best suited for their maintenance are discussed in the respective chapters of Part III.

II. Fattening

121. The object of fattening.—According to Armsby,[18] the accumulation of fatty tissue, as such, is of secondary importance in fattening, the main object being to otherwise improve the quality of the lean meat. To some extent during growth, and especially during fattening, there is a deposition of fat in the lean-meat tissue. A small portion of this may be deposited within the muscular fibers themselves, but a much larger part is stored between the bundles of fibers, constituting the so-called "marbling" of meat. This deposition of fat adds to the tenderness, juiciness, flavor, and digestibility of the meat, besides increasing its nutritive value. It seems possible that there is also an increase in the soluble or circulating protein and in other extractives of the muscles, resulting in a further betterment of the quality of the meat as an additional advantage from fattening.

122. Increase during fattening.—The changes in the composition of the bodies of farm animals during fattening were extensively studied by Lawes and Gilbert of the Rothamsted Station[19] from analyses of the entire bodies of oxen, sheep, and pigs slaughtered at different stages of fattening. They give data from which the following table is derived:

Percentage composition of the increase of fattening animals

Animal	Protein Per ct.	Fat Per ct.	Mineral matter Per ct.	Total dry substance Per ct.	Water Per ct.
Ox	7.7	66.2	1.5	75.4	24.6
Sheep	7.1	70.4	2.3	79.9	20.1
Pig	6.4	71.5	0.1	78.0	22.0

In most cases the animals studied had not entirely finished their growth when the tests began. The table shows that in 100 lbs. of live-weight gain made by the fattening ox, 7.7 lbs. was lean-meat tissue, 66.2 fat, 1.5 mineral matter, and 24.6 water. The sheep resembles the ox in character of increase during fattening, but stores more mineral matter, due to the growth of wool. The fattening pig stores very little mineral matter.

[18] U. S. Dept. Agr., Bur. Anim. Ind., Bul. 108. [19] Jour. Roy. Agr. Soc., 1860.

Henneberg and Kern[20] slaughtered a mature lean wether and determined the amount of lean meat and fat in the carcass. A similar wether was fed for 70 days and killed when half fat, and a third was slaughtered when extra fat, after being fed 203 days. The carcass of the second wether contained 3 times as much fat and that of the third nearly 4 times as much as the carcass of the unfattened sheep. During fattening these wethers made practically no gain in lean meat. Trials by Friske[21] seem to indicate that under some conditions even mature animals may make considerable gains in lean meat. Scientists agree, however, that as a rule the fattening of mature animals is what the term implies—the laying on of fat—with but relatively small storage of protein.

That animals fattened while growing will not only gain in fatty tissue but in lean meat is shown by the experiments of Waters, Mumford, and P. F. Trowbridge,[22] who analyzed the entire bodies of steers killed at various stages of fattening at the Missouri Station. The following table shows the composition of the carcass of a 748-lb. steer in thrifty growing condition and the composition of the gains made by other steers during fattening:

Composition of unfattened steer and gains during fattening

	Water Per ct.	Fat Per ct.	Protein Per ct.	Ash Per ct.
Carcass of unfattened steer......	56.4	18.6	18.8	5.7
First 500 lbs. of gain............	37.6	48.6	11.9	2.0
Second 500 lbs. of gain..........	17.8	75.6	5.2	1.5
Total 1,000 lbs. of gain..........	27.7	62.1	8.5	1.7

While the carcass of the steer killed before fattening was over half water, the first 500 lbs. of gain contained only 37.6 per ct. water and the second 500 lbs. but 17.8 per ct. The first half of the gain was 48.6 per ct. fat and 11.9 per ct. protein, showing marked increase in lean meat. In the last half of the gain 75.6 per ct. was fat and only 5.2 per ct. protein. The storage of ash was likewise less in the last 500 lbs. of gain. Thus, as a partly mature animal fattens it progressively makes less growth in lean meat and skeleton, and a larger part of the gain is fat.

123. Composition of steers of different ages.—For several years Haecker of the Minnesota Station[23] has been conducting extensive investigations on the food requirements of steers of different ages, in which he has had analyzed the entire carcasses of many animals. The following table shows the average composition of steers slaughtered at various stages, from birth up to a weight of 1,500 lbs.:

[20] Jour. Landw., 26, 1878, p. 549.

[21] Landw. Vers. Stat., 71, 1909, pp. 441–482.

[22] Information to the authors.

[23] Minn. Rpt. 21 and information to the authors.

*Average composition of steers at various stages**

Normal Weight	No. of steers	Water	Dry matter	Protein	Fat	Ash
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
100.........	5	71.84	28.16	19.90	3.99	4.27
200.........	4	70.46	29.54	19.14	5.98	4.42
300.........	3	66.31	33.69	19.02	10.18	4.49
400.........	5	65.78	34.22	19.29	10.59	4.34
500.........	5	62.86	37.14	19.17	13.76	4.21
600.........	3	61.99	38.01	19.42	14.00	4.59
700.........	4	60.34	39.66	18.60	16.58	4.48
800.........	3	58.43	41.57	18.80	18.53	4.24
900.........	3	54.10	45.90	17.66	24.08	4.16
1000.........	2	53.01	46.99	17.57	25.60	3.82
1100.........	1	48.03	51.97	16.18	31.91	3.88
1200.........	2	48.63	51.37	16.59	31.11	3.67
1400.........	1	47.77	52.23	16.15	32.57	3.51
1500.........	1	43.46	56.54	15.67	37.67	3.20

* Not including contents of the digestive tract.

The table shows that the percentage of water steadily decreases as the animal matures, falling from 72 per ct. in the calves to less than 50 per ct. in the 1500-lb. steer. The percentage of fat increases rapidly during the growth and fattening of the animal, increasing from 4.0 per ct. soon after birth to over 37 per ct. in the 1500-lb. steer. The protein and ash show less change than the water and fat, but decrease percentagely as the animals increase in weight. Haecker states that the storage of protein by the animal, which is rapid in early life, shows a marked slowing up when the animal reaches a weight of about 800 lbs. On the other hand, the gain in fat is most rapid after the steer reaches a weight of 600 lbs.

124. Origin of body fat.—The source of the fat which animals store in their bodies has been the subject of much controversy. Kellner, Armsby, Hagemann, and other modern authorities agree that the body fat of animals may originate either from the fat or carbohydrates of the food. Scientists still disagree upon the possibility of animal fat being formed thru the decomposition of protein. The preponderance of evidence favors such formation, as is later shown. (128)

125. Body fat from food fat.—Many experiments have conclusively shown that the fat in food, which has been acted on by the digestive fluids in the intestines, may be directly stored in the body tissues when supplied in large quantity.

Hofmann[24] allowed a dog to starve until its weight had decreased from 26.5 to 16 kilograms and the supply of fat in its body had practically disappeared, as shown by the increased decomposition of the protein tissues at that time. For 5 days this dog was fed large quantities of fat and only a little fat-free meat, during which time it gained 4.2 kgms. in weight. When slaughtered its body contained 1,353 grams of fat, only 131 of which could possibly have come from the protein fed. Hence

[24] Ztschr. Biol., 8, 1872, p. 153.

much of the fat formed during this time must have come from the fat of the food.

Henriques and Hansen[25] fed 2 three-months-old pigs barley meal together with oil. The first pig received linseed and the second cocoanut oil. Samples of the body fat were removed from the back of each pig thru incisions, and analyzed. The fat which had formed during the feeding resembled in odor, consistency, and composition the vegetable fat which had been fed. Later, when the feeds were reversed the body fat then formed showed a corresponding change in properties.

All the digested fat taken into the body of the animal beyond that required for maintenance cannot, however, be deposited as body fat, since considerable losses always occur thru the energy expended in digestion and metabolism. Kellner[26] states that in the case of carnivora, or flesh-eating animals, such as the dog, not more than 87.3 lbs. of body fat can be formed from 100 lbs. of pure fat supplied in the food. With herbivora, or animals which consume coarse forage, such as the horse, ox, etc., the work of moving the food thru the digestive tract, digesting it, and disposing of the waste is larger. Hence the amount of body fat which may be formed by these animals from 100 lbs. of digestible fat in the food consumed is much lower than with the carnivora, varying from 64.4 lbs. in the case of pure fats to 47.4 lbs. in the fats of roughages.

126. Fat from carbohydrates.—Scientists agree that the fat in the body of animals can be formed from carbohydrates. As early as 1842 Liebig maintained that animal fat was formed mainly from the carbohydrates, tho it might also originate from the protein of the food. The extensive experiments of Lawes and Gilbert of the Rothamsted Station,[27] conducted from 1848–1853 with more than 400 animals, clearly showed that much more fat was stored than could be derived from the fatty matter and protein of the food.

Soxhlet[28] fed 2 full-grown pigs a ration of 4.4 lbs. of rice meal for 5 days. One pig was then killed and its body analyzed, while the other was fed 4.4 lbs. of rice, daily, and later a ration of 3.3 lbs. of rice with some meat extract, both being foods which are almost free from fat. After 82 days this pig was also killed and its body analyzed. Assuming that the bodies of both pigs were of similar composition when the first was killed, Soxhlet found the quantity of fat formed in the body of the second pig and its source to be as follows:

	Grams
Maximum fat possible from fat in food	340
Maximum fat possible from protein in food	2,488
Minimum fat that must have been formed from carbohydrates in food	19,352
Total fat from 3 sources	22,180

It is shown that during the trial 22,180 grams of fat were formed. Deducting from this the sum of the maximum amounts of fat which

[25] Centbl. Agr. Chem., 29, 1900, p. 529.
[26] Ernähr. landw. Nutztiere, 1907, p. 143.
[27] Jour. Roy. Agr. Soc. VI, Pt. 1, 1895.
[28] Jahresber. Agr. Chem., 1881, p. 434.

could have been derived from the fat and the protein supplied in the food, there remains 19,352 grams of fat as the minimum which must have been formed from the carbohydrates in the food. Hence at least 87 per ct. of the fat formed by this pig during the trial was derived from the carbohydrates in the food.

The formation of fat by ruminants from the carbohydrates was first demonstrated by Kühn[29] with the aid of a respiration apparatus. Oxen were fed for long periods on meadow hay and starch, which provided a ration low in protein and fat. Kühn shows that even if all the carbon resulting from the digestion of the protein and fat in the food went to form fat in the body there still remained a large amount of deposited fat which could only have come from the carbohydrates of the food. These conclusions are confirmed by later experiments by Kellner,[30] also with oxen. In these later trials it is shown that 100 lbs. of digested starch or digested fiber yielded about 24.8 lbs., and 100 lbs. of digested cane sugar only 18.8 lbs., of body fat.

127. Fat from pentosans.—Tho no experiments have yet been carried on to show that body fat may be formed from pure pentosans, it is certain that these carbohydrates may aid in its formation. Kellner[31] fed oxen straw in which pentosans furnished 33 per ct. of the energy. The large deposits of fat which followed must have come in part from the pentosans of the food.

128. Fat from protein.—When a liberal protein diet supplies the animal with more energy than is necessary for its maintenance, not only may a part of the excess protein be deposited in the body as flesh, but the non-nitrogenous portion resulting from the cleavage of protein may be converted into either body fat or glycogen. Since body fat may be derived from the carbohydrates, and since glucose and glycogen may be formed from the proteins, it is reasonable to hold that body fat may be formed from the protein of the food. Demonstration of the direct formation of body fat from food protein is difficult, as it is almost impossible to induce animals to consume any large quantity of pure protein food. The consumption of protein must be relatively large to maintain the nitrogen equilibrium of the body, and so usually but a small excess available for the formation of fat remains above body requirements.

Investigations by Cramer[32] with cats, and by Voit[33] and Gruber[34] with dogs which were fed large amounts of lean meat, show that the protein it contained must have been the source of the fat which was stored in their bodies during the trials. Henneberg,[35] working with dogs, concluded that 100 lbs. of protein may, upon decomposition, yield 51.4 lbs. of fat. Rubner,[36] likewise experimenting with dogs, has shown that owing to the

[29] Landw. Vers. Stat., 44, 1894, pp. 1-581.
[30] Land. Vers. Stat., 53, 1900, pp. 1-450.
[31] Landw. Vers. Stat., 53, 1900, pp. 1-450.
[32] Ztschr. Biol., 38, 1899, p. 307.
[33] Jahresber. Tier-Chem., 22, 1892, p. 34.
[34] Ztschr. Biol., 42, 1901, p. 407.
[35] Landw. Vers. Stat., 20, 1877, p. 394.
[36] Ztschr. Biol., 21, 1885, p. 250.

losses of energy which occur in the decomposition of protein not more than 34.7 lbs. of fat can be formed from 100 lbs. of protein in the food.

Herbivora—the ox, horse, sheep, etc.—cannot be fed exclusively on protein, since such feeding causes intestinal disorders. Kellner,[37] experimenting with steers, added wheat gluten, which is principally composed of vegetable proteins, to a ration which was already causing a considerable deposition of fat. The feeding of 100 lbs. of gluten caused the deposition of 23.5 lbs. fat in addition to the fat due to the basal ration. Kellner maintains that this additional deposit was derived from the protein fed in the wheat gluten.

129. Body fat from nutrients.—The following table from Kellner[38] summarizes his studies on the amount of fat which may possibly be formed in the body of the growing ox from 100 lbs. of digestible matter of the several nutrients fed in combination with a basal ration already exceeding the maintenance requirements of the animal:

	Energy available for fat formation Therms	Possible fat Lbs.
Fat	204–259	47.4–59.8
Protein	102	23.5
Starch and fiber	107	24.8
Cane sugar	81	18.8

The table shows that if an ox is getting enough food for maintenance, supplying 100 lbs. of fat in addition may result in the storage of from 47.4 to 59.8 lbs. of body fat. For the other nutrients there is a smaller deposit, cane sugar forming only 18.8 lbs.

130. The ration for fattening.—Since the fattening of mature animals consists mainly in the storage of fat, there is no demand for a large supply of food protein. While the Wolff-Lehmann standards (Appendix Table IV) advise nutritive ratios of 1:5.4 to 1:6.5 for mature fattening cattle, 1:4.5 to 1:5.4 for fattening sheep, and 1:5.9 to 1:7.0 for fattening swine, numerous experiments have shown that mature animals of all classes can be successfully fattened on a much smaller allowance of crude protein.

Kellner[39] found that the gains of the mature ox remained unchanged whether 1 lb. of protein was fed with 4 or with 16 lbs. of carbohydrates, the total quantity of nutrients remaining the same. In such case the quantity of fat formed was in proportion to the nutrients digested in excess of the wants of the body. However, where less digestible protein is fed than 1 lb. to 8 or 10 lbs. of carbohydrates, the digestibility of the ration may be decreased. Kellner accordingly advises that for mature fattening cattle the nutritive ratio should never be wider than 1:10 or 12. In regions where alfalfa hay or other nitrogenous feeds are abundant and low in price and the carbohydrates relatively high in cost, it may be profitable to feed a ration with a narrow nutritive ratio. Animals in

[37] Landw. Vers. Stat., 53, 1900, p. 452.

[38] Ernähr. landw. Nutztiere, 1907, p. 158.

[39] Ernähr. landw. Nutztiere, 1907, pp. 418-420.

thin flesh should at first be liberally supplied with protein in order that their muscular tissues may develop. For such animals Kellner holds that the nutritive ratio should be about 1:6, with from 12 to 15 lbs. of digestible nutrients daily per 1000 lbs. of live weight.

Owing to the greater economy of gains by young animals, in this country the larger part of our meat-producing animals are fattened and marketed before maturity. Such animals are adding not only fat, but also considerable lean meat to their bodies as they fatten, and therefore require a more liberal supply of protein than mature animals. Skinner, Cochel, and King[40] in extensive trials at the Indiana Station have found that 2-year-old steers make larger gains and require less feed per 100 lbs. gain when fed rations with a nutritive ratio of 1:7 to 1:8 than when the ration has a wider nutritive ratio. In 4 trials fattening lambs made larger gains and required less feed per 100 lbs. gain when fed rations having an average nutritive ratio of 1:6.8 than when the nutritive ratio was 1:8.8.

It is important to bear in mind that since protein-rich feeds are usually high in price, the most profitable ration may not be the one producing the largest gains, the larger gains being in some cases offset by the higher cost of the ration containing an abundance of protein. Rations for fattening each kind and age of animals are discussed in detail in Part III.

131. Factors influencing fattening.—The deposition of fat in an animal depends primarily upon the quantity of food consumed in excess of maintenance and growth requirements. Fattening may take place at any age, tho the tendency of young animals to grow greatly reduces the proportion of food usually available for that purpose. Since the process of fattening depends upon the excess of digested nutrients over the wants of the body, it is evident that anything that decreases the waste due to external work or to excess of exercise, and which lessens the internal work of digestion and assimilation, may aid in fat formation. Exertion of any kind increases the oxidations going on in the body. Vigorous exercise must therefore be avoided in the case of fattening stock and milch cows. Supplying an abundance of feeds that are palatable, concentrated, and largely digestible tends to rapid fattening, because a large surplus of nutrients then remains after supplying the body needs, which surplus may go to form fat.

The disposition of an animal to fatten depends upon breed and temperament. While a wild animal, nervous and active, can be fattened only with extreme difficulty, domesticated animals are more quiet and usually fatten readily. The restless animal is rarely a good feeder, while the quiet one, which is inclined to "eat and lie down," will show superior gains. This is not due to difference in digestive or assimilative powers, but rather to the fact that the quiet animal has, from a given amount of food, a greater surplus of nutrients available for fat building.

132. Comparative fattening qualities.—Lawes and Gilbert[41] give the following data regarding the comparative fattening qualities of the steer,

[40] Ind. Buls. 153, 162, 167, 168, 178, 179. [41] Warington, Chemistry of the Farm.

sheep, and pig, based on trials in which there were required, on the average, for 100 lbs. gain: By steers, 250 lbs. oil cake, 600 lbs. clover hay, and 3500 lbs. swedes (rutabagas); by sheep, 250 lbs. oil cake, 300 lbs. clover hay, and 4000 lbs. swedes; by pigs, 500 lbs. barley meal.

Comparative returns from the steer, sheep, and pig

	Steer	Sheep	Pig
	Lbs.	Lbs.	Lbs.
Average live weight	1200	130	175
Per head per week			
Total dry food eaten	151	21	48
Digestible organic matter in food	106	16	40
Increase in live weight	13.6	2.3	11.3
Per 1,000 lbs. live weight per week			
Total dry food eaten	125	160	270
Digestible organic matter in food	88	121	227
Increase in live weight	11.3	17.6	64.3
Required for 100 lbs. increase			
Total dry food eaten	1109	912	420
Digestible organic matter	777	686	353

The table shows that the average 1200-lb. fattening steer will consume during one week 151 lbs. of dry food, containing 106 lbs. of digestible organic matter, and will gain 13.6 lbs. Because they are smaller the food consumed and the gains per head by the sheep and pig are much less. When the feed consumption and gains per 1000 lbs. of live weight are compared, however, it is seen that 1000 lbs. of pigs consume 270 lbs. of dry matter per week against 125 lbs. for steers. However, the gains of pigs are enough more rapid to more than balance the greater consumption of feed. While the pigs consume about 2.2 times as much feed per 1000 lbs. as the steers, they make nearly 6 times as much gain. The reason why pigs require less food to produce 100 lbs. of increase than either steers or sheep is largely that their food is more concentrated and digestible, so that a smaller proportion is consumed in the work of digestion and assimilation, leaving a larger surplus for producing gain.

133. Returns from feed.—The following by Jordan[42] shows the amount of food suitable for man returned by the different classes of farm animals for each 100 lbs. of digestible matter consumed:

Human food produced by farm animals from 100 lbs. of digestible matter consumed

Animal	Marketable product	Edible solids	Animal	Marketable product	Edible solids
	Lbs.	Lbs.		Lbs.	Lbs.
Cow (milk)	139.0	18.0	Poultry (eggs)	19.6	5.1
Pig (dressed)	25.0	15.6	Poultry (dressed)	15.6	4.2
Cow (cheese)	14.8	9.4	Lamb (dressed)	9.6	3.2
Calf (dressed)	36.5	8.1	Steer (dressed)	8.3	2.8
Cow (butter)	6.4	5.4	Sheep (dressed)	7.0	2.6

[42] The Feeding of Animals.

The table, which presents one side of a most complicated problem, shows that for 100 lbs. of digestible nutrients consumed:

The cow yields about 139 lbs. of milk, containing 18 lbs. of solids, practically all digestible.

The pig produces about 25 lbs. of dressed carcass. Allowing for water, bone, and gristle, there remains over 15 lbs. of edible dry meat.

The steer and sheep yield less than 10 lbs. of dressed carcass, nearly half of which is water. Deducting this and the bone and gristle, there remains only from 2.6 to 3.2 lbs. of water-free edible meat.

The cow easily leads all farm animals in her power to convert the crops of the field into human food, with the pig second, poultry following, and the steer and sheep coming lowest.

III. Studies on Growth and Fattening

134. Wide and narrow rations for growing steers.—At the Maine Station[43] Jordan studied the influence of a ration rich in crude protein and of one poor in crude protein on the rate of growth and character of the flesh formed by growing steers. Four high-grade Shorthorn steer calves, from 5 to 7 months old when the trial began, were used. Lot I, 2 steers, was fed a concentrate mixture of 2 parts linseed meal, 1 part corn meal, and 1 part wheat bran, which furnished a large amount of protein. Lot II, 2 steers, was given a mixture of 2 parts corn meal and 1 part wheat bran, furnishing much less protein. The roughage for both lots consisted mostly of timothy hay, some corn fodder and corn silage being fed during the first winter only. The ration fed Lot I was thus rich in crude protein, having an average nutritive ratio of 1:5.2, and was also high in mineral matter. Lot II was fed a wide ration, having a nutritive ratio of 1:9.7, which supplied much less protein and also less mineral matter. Both lots were liberally fed, tho there was no attempt to force growth. One steer in each lot was slaughtered at the end of 17 months and the remaining two at the end of 27 months, all carcasses being analyzed to determine whether any difference existed therein.

Results of feeding wide and narrow rations to growing steers

	Total gain	Digestible matter for 100 pounds gain	Composition of entire body except skin			
			Water	Protein	Fat	Ash
	Lbs.	Lbs.	Per ct.	Per ct.	Per ct.	Per ct.
Steer fed 17 months						
On narrow ration..	737	495	59.02	17.89	18.53	4.56
On wide ration....	552	686	56.30	17.82	20.27	5.61
Steer fed 27 months						
On narrow ration..	962	773	51.91	16.93	25.86	5.30
On wide ration....	1005	708	52.16	17.10	25.32	5.42

[43] Maine Rpt., 1895.

The table shows that during the first 17 months the steer on the narrow ration gained 185 lbs. more than the other on the wider one and that a given gain was made on less feed. The carcasses of both steers showed practically the same percentage of protein or lean-meat tissue, while that of the one getting the narrow ration had more water and less fat and ash. Of the steers fed 27 months, the one on the wide ration made the larger total gain and required less feed for 100 lbs. of gain. The water, protein, and ash in the bodies of these 2 steers were practically the same.

These data support the statement previously made (**116**), that a ration having a narrow nutritive ratio is conducive to the rapid growth of the young growing animal. On the other hand, when the body is partly or largely grown, the largest gains, which are then mostly fat, come from liberal feeding with rations which are rich in digestible carbohydrates and rather limited in crude protein—i.e., having a comparatively wide nutritive ratio. Doubtless more economical results than were secured with either lot would have been obtained had these steers been fed the narrow ration during the first 17 months or thereabouts, and then fattened on a wider ration. Trials with larger numbers of animals, already mentioned (**130**), show that the largest gains are made by 2-year-old steers when fed a somewhat narrower ration than the wide one fed by Jordan.

135. Feeding pigs corn only.—In 1884 Sanborn of the Missouri Agricultural College[44] conducted studies in which growing pigs fed exclusively on corn meal were compared with others fed on corn meal and either wheat middlings or dried blood. The corn-meal ration furnished an abundance of easily digested carbohydrates and fat, but was deficient in crude protein and mineral matter. The addition of dried blood or wheat middlings to corn meal formed a ration rich in crude protein and mineral matter as well as carbohydrates and fat. Sanborn showed that, compared with the corn-fed pigs, those getting rations rich in crude protein had a larger muscular development and more blood, and that some of their internal organs were larger.

Realizing the fundamental importance of Sanborn's studies, the senior author conducted numerous trials at the Wisconsin Station[45] in which dried blood, wheat middlings, field peas, and skim milk, with or without corn meal, were fed in opposition to corn meal alone. Shelton of the Kansas Station[46] fed pigs a mixture of wheat shorts and wheat bran in opposition to corn meal, potatoes, and tallow. At the Alabama Station[47] Duggar fed cowpeas, which are rich in crude protein, against corn meal. In France Fortier[48] duplicated a trial by the senior author, feeding skim milk, dried blood, and wheat middlings in opposition to corn meal. Thus at 5 widely separated points pigs were fed rations rich in crude protein and mineral matter, usually containing some corn meal, in opposition to

[44] Mo. Buls. 10, 14, 19.
[45] Wis. Rpts., 1886, '87, '88, '89.
[46] Kan. Bul. 9.
[47] Ala. Bul. 82.
[48] Ext. Trav. Soc. Cent. d'Agr., Dept. Seine-Inf., 1889, 1890.

corn meal alone, which is rich in carbohydrates and fat but low in crude protein and mineral matter. The following table summarizes the findings of two trials at the Wisconsin and one at the Kansas Station, these being typical of all:

Effect on pigs of rations rich in protein and ash, compared with corn alone

I. Daily gains, live weights, dressing percentage, and strength of bones

Station and feed	Av. daily gain	Live wt. at end of trial	Dressed carcass	Strength of thigh bone per 100 lbs. live wt.
Wisconsin	Lbs.	Lbs.	Per ct.	Lbs.
Lot I, Milk, middlings, blood	1.0	223	81.2	503
Lot II, Corn meal	0.7	187	80.2	380
Wisconsin				
Lot I, ⅓ blood, ⅔ corn meal	1.4	298	83.2	385
Lot II, ½ peas, ½ corn meal	1.2	277	82.3	471
Lot III, Corn meal	1.1	254	83.5	354
Kansas				
Lot I, Shorts, bran	1.4	211	76.8	357
Lot III, Potatoes, tallow, corn meal	1.1	183	79.8	332

II. Weight of internal organs and parts per 100 lbs. of dressed carcass

Station and feed	Blood	Liver	Kidneys	Tenderloin	Leaf lard
Wisconsin	Oz.	Oz.	Oz.	Oz.	Oz.
Lot I, Milk, middlings, blood	54.4	26.9	5.0	17.1	79.9
Lot II, Corn meal	41.3	24.3	4.2	13.8	89.3
Wisconsin					
Lot I, ⅓ blood, ⅔ corn meal	47.1	22.2	3.9	....	....
Lot II, ½ peas, ½ corn meal	44.7	21.3	3.4	....	....
Lot III, Corn meal	43.8	17.7	2.8	....	....
Kansas					
Lot I, Shorts, bran	50.4	44.7	7.4	13.0	65.1
Lot II, Potatoes, tallow, corn meal	36.8	33.8	5.8	10.0	75.3

The first division of the table shows that the pigs fed rations rich in crude protein and ash made heavier gains than those fed rations poor in these constituents. As a rule the pigs getting the rations rich in crude protein had a larger amount of blood and heavier livers and other organs per 100 lbs. of carcass, as is shown in the second division of the table.

The strength of the thigh bones was determined in the following manner: The 2 rounded, iron supporting edges of a machine used for testing the breaking strength of materials were set four inches apart. On these a thigh bone was placed, the rounded edge of the breaking-bar pressing down on the bone from above, midway of its length. The downward pressure was gradually increased, being measured by the tilting beam of the machine. Under the steadily increasing pressure the bone finally broke, its resistance at the time of breaking being recorded. The trials showed that the pigs fed the ration rich in crude protein had the strongest bones. In the first Wisconsin trial, as the table shows, the bones of the corn-fed pigs broke at an average pressure of 380 lbs. for each 100 lbs. of carcass, while those of the pigs fed milk, dried blood, and middlings broke at about 500 lbs.—a difference of 32 per ct. in favor of the pigs getting the ration rich in crude protein.

In the first Wisconsin trial the pigs getting milk, wheat middlings, and dried blood had over 54 oz., or nearly 3.5 lbs., of blood for each 100 lbs. of dressed carcass, while those getting only corn meal had less than 42 oz., or but little over 2.5 lbs. The livers and kidneys of the pigs fed the rations rich in crude protein were in all cases relatively heavier, as were also the tenderloin muscles, lying along the back, showing that a superior muscular development was associated with the larger internal organs, more blood, etc. On the other hand, the carcasses of the corn-fed pigs contained an unduly large proportion of fat. Analyses of the organs and parts of the pigs used in the second Wisconsin trial showed further that the corn-fed pigs had proportionately less dry matter in their blood and kidneys and a smaller amount of dry lean-meat tissue than those on the narrow ration.

Later investigations show that differences produced by the exclusive corn rations and those rich in crude protein were not entirely due to the difference in the supply of crude protein. In each case the ration rich in crude protein was also the richer in mineral matter, for corn is not only low in crude protein but it also lacks mineral matter.

To study the effect upon the carcass of varying the amount of protein in the ration when an abundance of mineral matter was supplied, Grindley and colleagues[49] at the Illinois Station analyzed the carcasses of pigs fed corn and varying amounts of blood meal from weaning, all animals being supplied with calcium phosphate in addition, to furnish a liberal amount of lime and phosphoric acid. Pigs fed rations very high in protein, containing 26 to 35 per ct. blood meal, had larger kidneys and livers, and heavier, stronger bones than when a ration containing only 7 per ct. blood meal was fed. No difference was found between the various lots in the forms of nitrogenous compounds in the protein tissues or in the distribution of the ash between the various organs of the body.

136. Effect on tenderloins of exclusive corn feeding.—At the Missouri Station[50] Forbes fed 6 lots, each of five 120-lb. pigs, on unlimited rations for 60 days. One lot was fed corn only, while the others received corn supplemented with the various by-feeds shown below. All rations but the one exclusively of corn had the same nutritive ratio. On slaughtering the pigs, portions of the tenderloin muscles were analyzed, with the results shown on the next page.

[49] Ill. Buls. 168, 169, 171, 173. [50] Mo. Bul. 81.

Composition of the tenderloin muscles of pigs variously fed

Supplement fed per 100 lbs. of corn	Water Per ct.	Protein Per ct.	Fat Per ct.	Ash Per ct.
Lot I, Corn only	71.5	19.2	7.28	1.11
Lot II, Wheat middlings, 81.8 lbs	72.9	20.7	5.04	1.15
Lot III, Linseed meal, n. p., 17.8 lbs	74.1	20.5	4.01	1.18
Lot IV, Soybeans, 19.6 lbs	72.9	20.9	4.79	1.13
Lot V, Tankage, 8.1 lbs	73.7	19.8	5.17	1.13
Lot VI, Germ oil meal, 39.4 lbs	73.5	20.5	4.67	1.08

It is shown that the muscles resulting from exclusive corn feeding had more fat and less water and protein than the others. The corn ration and the corn and germ oil meal ration, both low in mineral matter, produced muscle lower in ash than the other rations. While the muscles from the pigs fed exclusively on corn contained less protein than the others and were therefore really smaller in size, because of their high percentage of fat they would, on cooking, furnish meat which would be more juicy and toothsome than that of the other lots.

137. Discussion of the pig-feeding experiments.—In analyzing the two preceding experiments we should hold that the pigs given feeds rich in crude protein and mineral matter developed bodies that were normal in skeleton, muscles, and all internal organs. Those fed corn exclusively were prevented from building a normal body structure because of the insufficient and unbalanced supply of crude protein and a lack of enough mineral matter in their food. We should not forget that all parts of the normally nurtured body attain a certain normal development which cannot be materially increased beyond a constitutional limit. Only in a small degree can the stockman in a single generation increase by what he may feed the size of the bones and the muscles of the animals under his care. On the other hand, Nature sets no such close limitations on the amount of fat that may be stored. This varies according to inheritance, the nature and abundance of the food, the amount of exercise, etc. The skeleton, the muscles, and all the organs of the body increase during the plastic stage of youth and cannot be augmented in the mature animal. (**113**) The quantity of fat which the animal may lay on is limited during youth and is more easily and largely stored after maturity has been reached. (**122**)

These experiments should impress upon the stockman the plastic nature of the bodies of young, growing animals. They show it possible for immature animals living on unsuitable food to survive a long time and develop bodies that are dwarfed in size and made unnaturally fat. They help to show that Nature's plan is to first grow the body framework and afterwards to lay on the fat. They point to the reasonable, important, and far-reaching conclusion that if a pig or other young animal is improperly fed so as to modify its bones, muscles, and vital organs even a very little, and the process is repeated during several generations, the cumulative effects will be marked and permanently injurious. The practical lesson is taught that young animals should be nurtured on a combination of feeding stuffs that will develop the normal framework of bone, muscle, and all body organs. This calls for a ration containing crude protein and mineral matter not only in ample amount, but also of suitable composition for rapid formation of body tissues. Having developed the proper framework of bone, together with the enveloping muscular system and all the organs of the body, the food supply may then consist largely of carbohydrates and fat, which are the cheap and abundant sources of animal fat.

In America corn is the common feeding stuff for swine, and pigs show such fondness for it that harm often results because the practice of the feeder and breeder is guided by the appetite of the animal rather than by a knowledge of the composition and limitations of feeds. Let us not despise corn because when wrongly and excessively used, as it purposely was in these experiments with young, growing pigs, it fails to develop the normal framework of bone and muscle. Each feed has its function in the nutrition of animals, and only by its abuse can unfavorable results follow.

138. Growth under adverse conditions.—At the Missouri Station[51] Waters kept 15 steers, varying from fat show animals to those in ordinary farm condition, for long periods on rations sufficient for maintenance. Below are given the results obtained with 4 yearling steers kept at constant body weight:

Growth of steers maintained at constant body weight

Age at beginning	Length of period	Increase in			Decrease in width of chest	Decline in condition from—
		Height at withers	Length of head	Depth of chest		
Months	Months	Per ct.	Per ct.	Per ct.	Per ct.	
11	7	10.2	11.1	5.6	10.1	Good to com.
9.5	12	9.9	19.7	8.5	12.1	Med. to thin
16.5	12	6.8	12.0	6.0	10.6	Prime to com.
17	12	5.8	9.6	1.1	9.4	Prime to com.

The table shows that in each case there was a marked increase in the height of the animal at the withers, the length of head, and the depth of chest, denoting a growth of the skeleton. The decrease in width of chest shows a thinning of the flesh covering the skeleton, indicating that the stored fat was re-absorbed or withdrawn from the tissues in the effort to continue growth on insufficient food. Examination of the fat cells of these animals showed a uniform reduction in their size as compared with those of animals receiving liberal rations.

In other trials by Waters and P. F. Trowbridge[52] at the Missouri Station steers in a thrifty growing condition, weighing 573 to 740 lbs., were fed rations just sufficient to maintain their weight for various periods of time, and were then slaughtered and the carcasses analyzed.

[51] Proc. Soc. Prom. Agr. Sci., 1908. [52] Information to the authors.

Others were fed sub-maintenance rations on which they lost 0.5 lb. per head daily, and still other rations on which they made 0.5 lb. daily gain per head. Even the steers losing weight made steady growth in skeleton. A steer weighing 654 lbs. when placed on the experiment lost 199 lbs. in 12 months, but nevertheless gained 3.6 inches in height at withers, and 4.5 inches in length of body. While the carcass of the steer slaughtered and analyzed as a check animal at the beginning of the trial contained 56.5 lbs. of fatty tissue, that of an animal which had been given a ration just sufficient to maintain its weight for 12 months contained only 24.3 lbs. of fatty tissue. An animal which had lost 0.5 lb. daily in weight steadily for a year had used up practically all of its fatty tissues for body fuel. Indeed only 0.4 lb. of fatty tissue could be separated from the entire carcass of the animal.

The following table shows the changes which were produced in the composition of the fatty tissues, lean flesh, and skeletons of 3 of the animals, compared with the tissues of the steer slaughtered as a check animal:

Changes in body tissues of steers on scanty and liberal rations

	Steer I, check animal	Steer II, on maintenance 12 months	Steer III, losing 0.5 lb. per day for 12 mo.	Steer IV, gaining 0.5 lb. daily for 5 mo.
Fatty tissue	Per ct.	Per ct.	Per ct.	Per ct.
Water	19.0	36.2	81.2	18.5
Fat	74.8	50.8	4.6	73.4
Protein	6.0	13.6	9.7	6.5
Ash	0.2	0.5	1.1	0.2
Lean flesh				
Water	71.0	74.0	76.9	71.1
Fat	8.0	4.6	2.1	7.8
Protein	20.1	19.7	19.8	19.2
Ash	0.9	1.0	1.0	0.9
Skeleton				
Water	37.1	36.2	52.6	35.4
Fat	14.7	16.4	2.9	17.3
Protein	20.4	20.0	19.1	19.8
Ash	25.3	26.6	22.8	25.3

The table shows that in the case of Steer II, held at constant weight for 12 months, much fat had been withdrawn from the fatty tissue, being largely replaced by water. So far had the withdrawal of fat progressed in the case of Steer III, that the small amount of "fatty tissue" which was secured from the carcass contained 81.2 per ct. water and only 4.6 per ct. fat! With the withdrawal of fat the percentage of protein and ash had increased. The lean flesh suffered much less change than the fatty tissues, even in the case of Steer III, which lost nearly 40 per ct. of the lean meat in his body during the trial. The data show that on insufficient food the fat was withdrawn to a marked degree from the lean flesh of the body.

The skeleton is not affected by poor nutrition until practically all the fat has been removed from the fatty tissues and the muscles. In the case of Steer III the withdrawal of fat had gone so far that nearly all the fat had been removed from the marrow of the skeleton and replaced with water. Indeed, the marrow had practically disappeared and in its place was a watery, ill-smelling liquid. This re-absorption of fat takes place from all parts of the skeleton. In contrast with these changes, the protein and ash content was but slightly reduced, even in the case of Steer III.

In the process of fattening, the fat is laid on the body in a certain order, being deposited first and most rapidly in certain regions, while in others little is stored until fattening is well advanced. Waters states that the withdrawal of fat from the tissues occurs in the reverse order from which it was laid on—that first deposited being the last to be absorbed.

An experiment with two 8-months-old steers, one on full feed and the other on a maintenance ration, showed that on the whole the animal on full feed increased in height more rapidly than the one on maintenance. However, for a considerable period the poorly fed steer grew as rapidly as the other. Waters states that the length of the period during which poorly fed animals gain as rapidly in height as well nourished ones ranges from 70 to 120 days, depending on the constitutional vigor of the individual and the excess fat with which it starts. After this period the increase in height becomes less rapid, ceasing altogether in from 6 months to a year and a half, by which time the animal has become quite thin and has re-absorbed all fat not necessary to its life. For 5 months a steer fed less than a maintenance ration and losing in weight grew in height as fast as one on full feed.

Growth on scanty rations is not due directly to the fat re-absorbed from the body. The animal burns its stored fat to support the body, and the protein in its food is used for building body tissue. The supply of mineral matter in the maintenance ration used in these studies was probably sufficient to provide an excess for growth. The steers developed depraved appetites in a short time after being placed on scanty rations and ate considerable earth, possibly making use of some of its mineral matter.

Waters concludes that the young animal may advance to normal size by any or all of the following ways:

1. By growing steadily from birth to maturity.
2. By storing fat in a period of abundant food supply to assist in tiding over a limited period of sparse food supply without serious interruption of growth.
3. By prolonging the growth period.
4. By an increase in the rate of growth during a period of liberal feeding following a period of low nourishment and low gain.
5. By conserving the cost. Apparently the animal when kept for a long period on scanty food gets on a more economical basis than when

more liberally fed. A ration which is at first insufficient to maintain the animal may be capable later of keeping the animal at a constant body weight, and still later of causing gain.

139. Effects of checking growth.—Waters, Cochel, and Vestal[53] have conducted numerous experiments at the Kansas Station to determine the effect on the subsequent development of pure-bred beef steers of checking their growth for various periods by under-feeding. They report that supplying a young, growing animal with a scant ration for a short period only will have no permanent effect on its development. Even when insufficient feeding is continued for a year or longer, the animal will recover to a surprising extent when placed on liberal feed, making unusually rapid and economical gains. Osborne and Mendel[54] have shown that while the normal growth period of rats rarely exceeds 335 days, those whose growth has been checked by insufficient food will resume growth even at the age of 480 to 532 days.

The Kansas experiments show, however, that while a steer whose growth has been checked for a year or more may grow nearly as tall as one fed well all along, it is almost certain to have a smaller digestive capacity, narrower hips, flatter ribs, heavier shoulders, and lighter hind quarters, even when finished for market. The form of the highly developed beef animal has evidently been caused by broadening the animal thru heavy feeding while young. If insufficient feed is supplied to distend the digestive tract and force out the ribs and hips when yet plastic, the body of the animal will never attain the desired conformation.

These studies on growth are highly significant to the stockman. They show that under certain conditions it may be profitable to carry growing animals thru the winter on roughages alone, even tho they lose slightly in weight, for on a return to good pasture, animals in spare but thrifty condition make exceedingly economical gains. However, the breeder who seeks to develop his animals toward an ideal must supply ample feed during the whole growth period.

[53] Kansas Industrialist, May 10, 1913; Apr. 18, 1914; and information to the authors.

[54] Jour. Biol. Chem., 18, 1914, pp. 95–106.

CHAPTER VI

PRODUCTION OF WORK, MILK, AND WOOL

I. Production of Work

It has long been known that muscular exertion or external body work greatly increases the amount of food material burned or broken down in the body, but scientists have disagreed as to whether one or all of the nutrients—protein, carbohydrates, or fat—furnishes the energy. Liebig, "the father of agricultural chemistry," held that the protein of the muscular tissues was the only material broken down in producing voluntary and involuntary motions, whether of the limbs, heart, or other parts of the body.

140. Waste of protein tissues during work.—That protein is not an important source of body energy was shown by Fick and Wislicenus,[1] who in 1865 ascended the Faulhorn, an Alpine mountain. While climbing the mountain these investigators consumed only non-protein food; i. e., starch, sugar, and fat, and during this time they collected all the urine passed. The amount of nitrogen excreted in the urine during the trial follows:

Nitrogen excretion during mountain climbing

	Total nitrogen excreted		Nitrogen excreted per hour (average)	
	Fick	Wislicenus	Fick	Wislicenus
	Grams	Grams	Grams	Grams
Night before ascent	6.92	6.68	0.63	0.61
During ascent	3.31	3.13	0.41	0.39
After ascent	2.43	2.42	0.40	0.40
Night after ascent	4.82	5.35	0.45	0.51

The table shows that only about two-thirds as much nitrogen was excreted per hour during and immediately after the climb as prior to it, when there was more or less residue in the system from the previous meal containing protein. Had the nitrogenous tissues or the muscles of the body been broken down directly in proportion to the labor performed, there would have been a large increase in the nitrogen excretion during and following this fatiguing work; but such was not the case. Measured by the nitrogen in the urine, the protein broken down during the trial could not possibly have furnished energy for more than one-third of the work done by these men in lifting their bodies to the top of the mountain.

[1] Jour. Roy. Agr. Soc., 1895; U. S. Dept. Agr., Office of Expt. Sta., Bul. 22.

From this trial and experiments by Voit, Pettenkofer, and Parks it was decided that only carbohydrates and fats were oxidized and burned in the production of muscular energy. Still later experiments by Argutinsky, Zuntz, and others have shown that when carbohydrates and fat are sufficient in amount they furnish all the muscular energy, and in such cases the breaking down of protein is not increased during work. However, if the supply of carbohydrates and fat in the food is insufficient, some of the energy for the production of work may be furnished thru the breaking down of protein, with a resultant increase in the nitrogen excretion in the urine.

141. Excretion of carbon dioxid.—Whether the material burned to furnish muscular energy be carbohydrates, fat, or protein, carbonic acid gas will be produced, the quantity directly depending upon the amount of work done. This was shown by Smith,[2] who determined the quantity of carbonic acid gas exhaled by the horse when at rest and performing labor as follows:

Form of work	Cubic feet per hour
At rest	1.03
Walking	1.10
Trotting	2.95
Cantering	4.92
Galloping	14.97

Thus, unlike the nitrogen excretion, the amount of carbon dioxid exhaled per hour is increased by the performance of work, and depends upon the work done in that time.

142. Production of muscular energy.—We know that in doing work the muscles of the body contract; that is, become shorter and thicker. Yet in spite of all the study of scientists we do not yet know definitely the direct cause of muscular contraction. How the nutrients stored in the muscular tissues are converted into the energy of muscular action is still an unsolved question. We do know, however, some of the processes which take place in the working muscles.

The most significant change which takes place during muscular contraction is the increased production of carbon dioxid, already noted, which seems to bear a definite relation to the amount of internal and external work performed. There is also a large increase in the amount of oxygen taken up by the muscles from the blood during work. The increase in oxygen consumed and carbon dioxid given off might lead to the conclusion that the activity of the muscle during contraction is due to simple oxidation, such as occurs when fuel is burned. However, certain facts which cannot be dwelt upon here lead scientists to believe that the chemical changes by which energy is liberated are not simple oxidations, but are more in the nature of sudden decompositions or cleavages of some complex substance or substances built up in the muscle during rest, carbon dioxid being evolved in such cleavage.[3] Part of

[2] Jour. Physiol., 1890, No. 1; U. S. Dept. Agr., Office of Expt. Sta., Bul. 22.
[3] Armsby, Principles of Animal Nutrition, 1903, p. 187.

the energy liberated in this decomposition appears as heat, and another part as mechanical work.

Glycogen, or animal starch, is stored in the muscle during rest, forming between 0.5 and 0.9 per ct. of the weight of well-nourished muscle in the resting condition. (**60**) A smaller quantity of glucose is also found in the muscular tissues. During muscular activity this stored glycogen and glucose disappear more or less, in proportion to the extent and duration of the contractions, so that after prolonged muscular activity or hard work the supply may be entirely exhausted. Tho the amount of these carbohydrates in the body tissues at any one time is small, a supply, especially of glucose, is being continuously produced from the food nutrients or body tissues to replace that oxidized in the production of work. As the larger part of the food of farm animals consists of carbohydrates, the oxidation of the glucose formed from them probably furnishes most of the energy for the production of heat and work by these animals. To supply the muscles with the necessary oxygen and also carry away the waste products formed during muscular exertion, the circulation of the blood must be hastened and larger quantities of air be taken in by the lungs.

143. Source of muscular energy.—All the organic nutrients absorbed from the food, not only the carbohydrates and fats, but also the proteins and apparently the pentosans, serve as sources of energy to the body. Under normal conditions the non-nitrogenous nutrients and the glycogen are first drawn upon for the production of work, no more protein being broken down than during rest. If the non-nitrogenous nutrients do not suffice for the production of muscular energy, then the body fat is next drawn upon. If this is insufficient or is much diminished by continued work, then as the last resort the muscles or other protein tissues will be called upon to furnish the needed energy.

144. Relative value of nutrients.—Investigations by Zuntz and his associates show that the value of each of the different classes of food nutrients for the production of work depends upon the total energy it contains. In one experiment[4] the diet of a man turning a wheel consisted, during separate periods, chiefly of either fat, carbohydrates, or protein. For 1 unit (kilogrammeter) of work the following amounts of energy were expended:

Period	Nutrient eaten	Energy expended per kgm. of work. Cal.
I	Protein	11.92
II	Carbohydrates	11.54
III	Fat	9.53
IV	Protein	10.78
V	Fat	9.25

It is shown that approximately the same fuel rations were required to produce a given amount of work whether the fuel was protein, carbohydrates, or fat. It will be noticed that the energy expended was less in

[4] Arch. Physiol. (Pflüger), 83, 1901, p. 564.

the last trials on account of the proficiency which had been attained in the work.

145. Energy requirements for work.—The total energy required to produce a certain amount of external work depends upon many factors. Experiments by Zuntz[5] with the horse show that an increase in the speed at which work is performed results in an increased expenditure of energy per unit of work. Practice in performing a certain work lessens the energy expenditure for that particular form of labor. In experiments upon himself Gruber[6] found that in climbing a tower the amount of carbon dioxid exhaled and hence the energy expended was decreased by 20 per ct. after training for 2 weeks. In experiments by Löwy[7] on himself, and by Zuntz[8] upon horses, fatigue caused an increase of from 14 to 41 per ct. in the amount of energy expended in performing a given amount of work. This increased expenditure of energy is largely due to the fact that with increasing fatigue the muscles normally used, and which are thus the most efficient in performing the given work, are put out of use. Then other less used muscles are called upon to a constantly increasing degree, and these cannot perform the work so efficiently or economically.

The part of the expended energy appearing in useful work varies in accordance with the build of the animal, the development of its muscular apparatus, and the structure of its extremities which bring about the work. Zuntz found great variations in the energy expended by different horses of the same weight in traveling upon a level track, a lame horse expending 99 per ct. more energy than a sound one. In the work of climbing a grade he found a variation with different horses of as much as 52 per ct. in the proportion of the total energy expended which appeared as useful work. An animal which is able to accomplish one form of work most economically may have to expend an unusual amount of energy at other kinds of work. For example, horses bred for generations to the saddle can carry the rider with smaller expenditure of energy than those whose breeding, form, and qualities specially fit them for draft purposes.

Certain forms of labor are performed with greater economy of energy than others. Katzenstein[9] found in experiments with men that about 65 per ct. more energy was used in turning a wheel with the arms than was required when the same work was done with the legs.

146. The animal as a machine.—The extensive investigations by Zuntz and associates with men, dogs, and horses show that, aside from small variations due to the nature of the work and other factors, the part of the energy expended which is actually transformed into external work is quite constant for each class. With animals at moderate work the part of the energy which appeared in external work varied from 28.8

[5] Landw. Jahrb., 27, 1898, Sup. III.
[6] Ztschr. Biol., 38, 1891, p. 466.
[7] Arch. Physiol., 49, 1891, p. 413.
[8] Landw. Jahrb. 27, 1898, Sup. III.
[9] Wolff, Farm Foods, p. 84.

to 36.6 per ct. of the total energy expended. On the average it is reasonable to hold that with men and animals about one-third of the energy consumed in muscular exertion is recovered as external work. The rest takes the form of heat within the body, and is lost so far as the production of work is concerned. This does not take into account the energy lost in the excreta, nor that expended for digestion, assimilation, and the maintenance of the body during rest. Atwater[10] found that a man returned 19.6 per ct. of the fuel value of his food as external work. The best steam engines have about the same efficiency, while the average engine falls below 10 per ct. Gasoline engines range in efficiency from 10 to 27 per ct. Thus, as a mere machine the animal body compares favorably with the best modern engines. In addition to performing external work the body must prepare and transport its own fuel, store it until needed, make all repairs, and maintain a definite temperature, as well as direct, move, and control itself. When all these functions are considered, the marvelous perfection of the animal body as a machine becomes apparent.

147. The body not a heat machine.—The animal body is not an engine which converts heat into mechanical work. As Armsby[11] points out, the power of a steam engine is derived directly from the heat produced by the burning coal, but in the animal body the energy of the food is transformed into work in quite another way. While the fuel value of a food represents the total amount of energy it can liberate in the body, a varying part of this total energy is always set free in the body as heat, and this heat can do no external work, tho it warms the body. Only that part of the food energy which is liberated in other forms than heat can be utilized for the production of either internal or external work. By processes still unknown the animal machine produces muscular energy, heat, light, and electricity with an efficiency greater than any machine made by man. With animals the fuel is burned at low temperature. The glow worm and firefly produce light without sensible loss of heat or other energy, and the torpedo fish and electric eel generate electricity by means unknown. Scientists and inventors alike are baffled by the mysterious and wonderful processes continuously occurring in the animal body.

As the horse is the principal animal machine for performing work, this subject is appropriately continued in Chapter XVIII.

II. Production of Milk

148. Secretion of milk.—Milk, the marvelous fluid designed by Nature for the nourishment of the young of all mammals, is secreted by special organs, called the mammary glands. Scientists disagree as to the exact process by which the milk is formed in the small sac-like bodies, known as *alveoli,* in the udder. However, we do know that the blood, laden with nutrients, is brought by the capillaries of the udder to the alveoli.

[10] U. S. Dept. Agr., Office Expt. Sta., Bul. 136. [11] Penn. Bul. 84.

The nutrients then pass thru the walls of the capillaries into the alveoli, where by one of Nature's wonderful processes they are converted into milk, which differs entirely in composition from the blood, whence it originates. The chief proteins of milk—casein and milk albumin—differ from all other proteins of the body, and the milk fat also has entirely different properties from the body fat of the same animal. Milk sugar, the carbohydrate of milk, is found nowhere else in the body. While the blood contains much more potassium than sodium, in milk sodium predominates.

From the alveoli the milk passes into the network of milk ducts. In some animals the large milk ducts open directly on the surface of the teat, but in others, including the cow, they open into a small cavity, called the milk cistern, which is just above the teat. Most of the milk yielded at one milking is secreted during the milking process, for in the udder there is room for the storage of but a small part of the total amount produced.

Tho the secretion of milk is involuntary and cannot be prevented by the animal any more than can breathing or the circulation of the blood, the flow may be reduced by nervousness caused by fright, an unfamiliar attendant, or other unusual excitement. The animal has considerable power to "hold up" the milk already secreted in the udder, by contracting the ring of muscle which partially separates the milk cistern from the teat, and similar muscles guarding the milk ducts.

Only in most exceptional cases does the true secreting tissue of the mammary gland develop before the animal becomes pregnant. However, when an extract is made from an unborn fetus and injected into the blood of a virgin animal, the mammary gland develops just as tho the animal were pregnant. This leads scientists to believe that in the developing fetus a mysterious chemical messenger, or "hormone," is formed, which is carried by the blood to the udder, and there stimulates the development of the alveoli—an example of the surprising degree to which the activities of the body are dependent on each other.

149. The source of fat in milk.—For many years it was believed that the cow could form the fat of milk only from fat in her food. This was disproved by Jordan and Jenter[12] of the New York (Geneva) Station in an ingenious experiment. A thousand lbs. of hay and 1500 lbs. each of corn meal and ground oats were sent to a new-process oil-meal factory, where nearly all the fat was extracted with naphtha in the percolators employed for extracting the oil from crushed flax seed. (253) The almost fat-free feeds were returned to the Station and afterwards fed to a cow which had freshened about 4 months before. For 95 days the cow lived on these nearly fat-free feeds, yet during this period she gave 62.9 lbs. of fat in her milk. The food she consumed contained but 11.6 lbs. of fat, of which only 5.7 lbs. was digested. Hence at least 57.2 lbs. of the fat found in the milk must have been derived from some other

[12] N. Y. (Geneva) Bul. 132.

source than the fat in the food. This fat could not have come from the body of the cow, for Jordan writes: "The cow's body could have contained scarcely more than 60 lbs. of fat at the beginning of the experiment; she gained 47 lbs. in weight during this period with no increase of body nitrogen, and was judged to be a much fatter cow at the end; the formation of this quantity of milk fat from the body fat would have caused a marked condition of emaciation, which, because of an increase in the body weight, would have required the improbable increase in the body of 104 lbs. of water and intestinal contents."

Jordan concludes that not over 17 lbs. of the fat produced during the trial could possibly have been produced from the protein supplied in the food. It is most evident that a large part of all the fat produced by this cow must have come from the carbohydrates in her feed, and so a long disputed question is at length settled.

150. Nutrients required for milk production.—To aid in showing the nutrients required for the production of milk, let us compute the amount of product yielded by a well-bred dairy cow in the course of a year. Such an animal, of no unusual ability, should yield 8000 lbs. of milk of average quality. Taking the composition shown in a previous table (**115**), we find that she will produce annually in her milk 272 lbs. of protein, 296 lbs. of fat, 392 lbs. of milk sugar, and 56 lbs. of mineral matter. This is 56 per ct. more protein, 30 per ct. more non-nitrogenous nutrients (fat and carbohydrates), and 19 per ct. more mineral matter than is contained in the entire body of a fat 2-year-old steer weighing 1200 lbs. (**29**)

Thus each year the cow yields more protein and mineral matter than has been built into the body of the steer during its entire life. At the same time she is also storing considerable protein and mineral matter in the developing body of her unborn calf. It is therefore evident that, far different from the requirements of the mature horse at work or of a mature fattening animal (**140,130**), the cow needs a liberal supply of protein and mineral matter. To yield the great amount of nutriment in the milk a ration supplying a large amount of net nutrients is also necessary, for energy used up in the mastication, digestion, and assimilation of such feeds as straw is of no value for the formation of milk. We have seen (**118**) that for growth individual proteins have widely different values. Hart and Humphrey[13] have found in recent metabolism experiments with dairy cows at the Wisconsin Station that proteins from various sources are of different worth for milk production. In these trials cows were fed a basal ration of corn stover, which supplied but a small amount of digestible protein. To this ration was added corn or wheat grain or by-products (much of the protein in which is unbalanced in composition) or milk protein, supplied in the form of skim-milk powder and casein (furnishing proteins which are complete in composition). The percentage of the digestible protein of these rations which was used

[13] Information to the authors.

by the cows for milk production and the formation of body protein was 40 per ct. with the corn ration, 34 per ct. with the wheat ration, and 58 per ct. with the milk protein ration. Such complete proteins as are furnished by milk are thus apparently higher in efficiency for milk production.

Since most of the scientific studies of the factors influencing the production of milk have been conducted with the dairy cow, the discussion of milk production as relating to that animal is continued in Chapters XXI to XXV. The requirements of the mare, ewe, and sow for the production of milk are also treated in the respective chapters of Part III.

III. Wool Production

151. Composition of wool.—Aside from moisture and dirt, "wool" is made up of pure wool fiber and yolk, the latter including the suint and the wool fat. The wool fiber is practically pure protein, and is of the same chemical composition as ordinary hair, but differs in being covered with minute overlapping scales. The suint, chiefly composed of compounds of potassium with organic acids, comprises from 15 to over 50 per ct. of the unwashed fleece, being especially high in Merinos. As suint is soluble in water, most of it is removed by washing the sheep or fleece, and less is present in the wool of sheep exposed to the weather. The fat, often incorrectly called yolk, is a complex mixture of fatty substances, insoluble in water, and may make up 8 to 30 per ct. of the weight of a washed fleece.

152. Requirements for wool production.—Owing to the large amount of protein stored by sheep in their fleece, their ration should contain somewhat more protein than rations for cattle or swine at the same stage of maturity. As is shown in the next chapter, this is taken into consideration in the various feeding standards which have been formulated for various classes of animals. With ewes which are either pregnant or suckling lambs, there is a double demand for food protein, which makes a liberal supply especially advisable. Tho the suint of wool is rich in potassium, this constituent is amply supplied by all usual rations, since practically all the common roughages are rich in potassium, and most concentrates carry a fair amount.

Experiments by Wolff[14] and Henneberg[15] show that when sheep are fed insufficient food to maintain their weight, the yield of wool is considerably diminished. On the other hand, according to Warington,[16] the production of wool hair and wool fat is practically no greater when a full-grown sheep receives a liberal fattening diet than when it is maintained in ordinary condition. Feeding lambs liberally produces a larger body and consequently a heavier fleece. At the Wisconsin Station[17] Craig found that lambs fed grain from an early age sheared about 1 lb.

[14] Landw. Vers. Stat., 1870, p. 57.
[15] Jour. Landw., 12, 1864, p. 48.
[16] Chemistry of the Farm.
[17] Wis. Rpt. 1896.

more of unwashed but practically the same amount of washed wool as those getting no grain until after they were weaned. The early feeding had produced more yolk but no more wool fiber.

The strength of the wool fiber is dependent on the breed, the quality of the individual sheep, and the conditions under which they are reared. Conditions which check the growth of the wool, such as insufficient feed, undue exposure, or sickness, will produce a weak spot in the wool fiber, thus lessening its strength. The feed and care for the flock should therefore be as uniform as possible. Certain regions or districts may produce wool of superior or inferior quality, due to the climate, soil, topography, and the forms of vegetation.

CHAPTER VII

FEEDING STANDARDS—CALCULATING RATIONS

I. Early Feeding Standards

In the preceding chapters we have considered the functions of the various nutrients in the nourishment of animals and have studied the general requirements for maintenance, growth, fattening, and the production of work, milk, and wool. To guide the farmer in choosing and computing rations for his stock, scientists have put these requirements into definite form thru the drawing up of *feeding standards*. These are tables showing the amount of each class of nutrients which, it is believed, should be provided in rations for farm animals of the various ages and classes, to keep them in the best condition and secure maximum production.

At the beginning of the last century almost nothing was known concerning the chemistry of plants and animals. The farmer then gave his stock hay and corn without knowing what there was in this provender that nourished them. But science soon permeated every line of human activity, and agriculture was benefited along with the other arts. Davy, Liebig, Boussingault, Henneberg, Wolff, Lawes and Gilbert, and other great scientists were early laying the foundations for a rational agricultural practice based on chemistry, and animal feeding gained with the rest.

153. Hay equivalents.—The first attempt to express the relative value of different feeding stuffs in a systematic manner was by Thaer[1] of Germany, who in 1810 published a table of hay equivalents with meadow hay as the standard. According to this writer the amounts of various other feeding stuffs required to equal 100 lbs. of meadow hay in feeding value were:

91 lbs. clover hay	417 lbs. rutabagas
91 lbs. alfalfa hay	602 lbs. cabbages
200 lbs. potatoes	625 lbs. mangels

Naturally opinions on feed values varied, and so there were about as many tables of hay equivalents as there were writers on the subject.

154. The first feeding standard.—Chemistry having paved the way, Grouven[2] in 1859 proposed the first feeding standard for farm animals, based on the crude protein, carbohydrates, and fat in feeding stuffs.

[1] Landwirtschaft, New ed., 1880, p. 211.

[2] Feeding Standard for Dom. Anim., Expt. Sta. Rec., IV; also Agriculturchemie, Köln, 1889, p. 834.

This, however, was imperfect since it was based on the total instead of the digestible nutrients.

155. The Wolff feeding standards.—In 1864 Dr. Emil von Wolff, the great German scientist, presented in the Mentzel & von Lengerke's Agricultural Calendar[3] for that year the first table of feeding standards based on the digestible nutrients contained in feeding stuffs. These standards set forth the amount of digestible crude protein, carbohydrates, and fat required daily by the different classes of farm animals.

The value and importance of the Wolff standards were at once recognized; and with their promulgation and adoption came the first widespread effort toward the rational feeding of farm animals. The Wolff standards were first brought to the attention of the American people in 1874 by Atwater,[4] America's worthy pioneer in the science of animal nutrition. Armsby's Manual of Cattle Feeding, based on Wolff's book[5] on the same subject, appeared in 1880.

The Wolff feeding standards appeared annually in the Mentzel-Lengerke Calendar down to 1896. From 1897 to 1906 they were presented by Dr. C. Lehmann of the Berlin Agricultural High School with some modifications. In 1907 Dr. O. Kellner, the talented director of the Möckern (Germany) Experiment Station, took charge of this portion of the Calendar and substituted tables and feeding standards based on starch values, as elsewhere briefly presented in this work. (**170**)

The numerous feeding experiments which have been carried on since the Wolff-Lehmann standards were formulated have given us a more complete knowledge of the nutrient requirements of the various classes of farm animals than was possessed by these pioneers in the field of animal nutrition. Naturally such results show that the standards set forth by Wolff and Lehmann are in some respects inaccurate. Taking these facts into consideration later scientists have formulated other standards which are presented elsewhere in this chapter. The Wolff-Lehmann standards are briefly explained first on account of their historical and foundational importance.

II. The Wolff-Lehmann Feeding Standards

156. The Wolff-Lehmann standards.—The nutrient requirements of the various classes of farm animals, as prescribed in the Wolff-Lehmann standards, are given in Appendix Table IV. From this table the following examples have been selected for purposes of study:

[3]Published annually by Paul Parey, Berlin, Germany.
[4]Rpt. Me. State Bd. Agr., 1874; Rpt. Conn. Bd. Agr., 1874-5.
[5]Fütterungslehre, 1st ed., 1874.

Digestible nutrients required daily by farm animals per 1000 lbs. live weight

Animal	Dry matter	Digestible nutrients			Nutritive ratio
		Crude protein	Carbo-hydrates	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.	
Ox, at rest	18	0.7	8.0	0.1	1 : 11.8
Fattening cattle, 1st period	30	2.5	15.0	0.5	1 : 6.5
Cow, yielding 22 lbs. milk	29	2.5	13.0	0.5	1 : 5.7
Horse, at medium work	24	2.0	11.0	0.6	1 : 6.2

The table shows that according to Wolff's teachings a 1000-lb. ox at rest, neither gaining nor losing in weight, requires for 1 day's maintenance 18 lbs. of dry matter containing the following digestible nutrients: 0.7 lb. crude protein, 8.0 lbs. carbohydrates, and 0.1 lb. fat, with a nutritive ratio of 1:11.8. Tho the ox is resting, work is still being performed; the beating of the heart, mastication, digestion, standing, breathing—all the manifestations of life in fact—imply internal work and call for energy and for repair material.

When the animal is growing, fattening, giving milk, or doing external work, a larger quantity of nutrients must be supplied than for maintenance, as the table shows. For the cow yielding 22 lbs. of milk daily, the standard calls for the following quantities of the several digestible nutrients: Crude protein 2.5 lbs., carbohydrates 13.0 lbs., and fat 0.5 lb. These have a nutritive ratio of 1:5.7, which is much narrower than for the ox at rest. In his effort to attain the proper standard Wolff[6] reasoned that, since pasture grass is the natural food of the dairy cow, the nutritive ratio of such grass might most properly serve as the chosen standard.

157. Notes on the Wolff-Lehmann standards.—Later investigations have shown that the Wolff-Lehmann standards are only approximately correct. Kühn of the Möckern Station[7] found that the 1000-lb. ox can be maintained on 0.7 lb. of digestible crude protein and 6.6 lbs. of digestible carbohydrates. Kellner, who was Kühn's successor, has practically adopted the Kühn standard as will be shown later. (**170**) It has been previously pointed out that Armsby succeeded in maintaining steers for 70-day periods on rations containing only 0.5 lb. of digestible true protein per 1000 lbs. live weight. (**94**) Whether this allowance would satisfactorily maintain animals in good health over still longer periods has not yet been definitely shown.

Haecker of the Minnesota Station[8] found that the 1000-lb. dry, barren cow can be maintained on 0.6 lb. of crude protein, 6 lbs. of carbohydrates, and 0.1 lb. of fat, all digestible. For the maintenance

[6] Farm Foods, Eng. Ed., p. 224.
[7] Landw. Vers. Stat., 44, p. 450.
[8] Minn. Bul. 79.

of the 1000-lb. cow producing milk he would allow 0.7 lb. of crude protein, 7 lbs. of carbohydrates, and 0.1 lb. of fat, all digestible. In his standard, which is presented later (**182**), he holds that the Wolff-Lehmann allowance of crude protein for the cow in milk may be advantageously cut 19 per ct. or more, unless feeds rich in that nutrient are available at relatively low cost. Woll of the Wisconsin Station[9] likewise found that the Wolff standard for dairy cows was higher in crude protein than necessary.

The Wolff allowance of crude protein for fattening animals may be materially reduced without decreasing the rate of gain. It has also been found that less protein is needed by the work horse than these standards recommend. These various findings are taken into consideration in the "Modified Wolff-Lehmann Standards" which are presented later in this chapter.

Altho we now have more accurate guides to the nutrient requirements of certain classes of animals than furnished in the Wolff-Lehmann standards, both students and stockmen should, first of all, familiarize themselves with the Wolff standards on account of their historical interest and because they are still widely and helpfully used in computing rations. These standards, coupled with tables of the digestible nutrients in feeding stuffs, such as Appendix Table III of this work, have been profoundly useful in advancing the great art of feeding farm animals. Having familiarized himself with the Wolff-Lehmann standards, one is prepared for the study of other more accurate systems and standards now in the process of formation.

III. Calculating Rations for Farm Animals

158. General requirements of satisfactory rations.—The various feeding standards make recommendations only in regard to the amounts of dry matter, of the various nutrients, and, in the case of the Kellner and Armsby standards, of the net energy which the ration should supply. However, the following highly important factors should also be taken into account in computing rations for farm animals.

159. Suitability of feeds.—The feeds selected for any animal should be such that they will not injure its health or the quality of the product yielded. Feeds which are suited to one class of farm animals may not be adapted to others. Again, a given feed may give satisfactory results when combined with certain other feeds, yet in other combinations it may prove unsatisfactory. A few examples of such conditions are furnished in the following: Cottonseed meal in moderate amount is an excellent feed for cattle, sheep, and horses, yet it is so frequently poisonous to pigs that feeding the meal, as at present prepared, to these animals cannot be advised. (**249**) While there is always danger from using feeds damaged by mold, such material may often be eaten with

[9] Wis. Rpt. 1894.

impunity by cattle when it would poison horses or sheep. (**397**) Timothy hay, which is the standard roughage for the horse, is unsatisfactory for the dairy cow, and may cause serious trouble with sheep on account of its constipating effect. (**312**)

Feeding cows a heavy allowance of ground soybeans produces unduly soft butter, while an excess of cocoanut meal makes the butter too hard. (**256, 260**) Peanuts and soybeans produce soft lard when forming too large a part of the ration of fattening pigs. (**258**)

It is often highly beneficial to add wheat bran or linseed meal to the ration on account of their slightly laxative effect. (**218, 254**) On the other hand, when animals are already receiving such laxative feeds as silage, pasture grass, and legume hay, the use of bran or linseed meal may be unwise.

160. Bulkiness of ration.—We have already seen that at least with the horse and with young ruminants the ration must contain some roughage to distend the digestive tract properly. (**106**) Furthermore, for the best results the proportion of concentrates and roughages in the ration should be regulated according to the kind and class of animal to be fed and the results sought. Cattle, sheep, and horses can be wintered satisfactorily on roughages alone, if of suitable quality. (**80, 91**) Even brood sows may be maintained chiefly on legume hay, when not suckling their young. In the rations for growing and fattening animals and those at work or in milk, a considerable part of the ration should consist of concentrates. The various feeding standards recognize these facts in the amount of dry matter which they prescribe in the rations for the different classes of animals. Obviously, when the requirement of digestible nutrients or of net energy is high compared with the total amount of dry matter advised, the proportion of concentrates in the ration must be large. On the other hand, for the mere maintenance of animals the standards call for a much smaller amount of digestible nutrients or of net energy compared with the amount of total dry matter.

161. Mineral matter.—In the various feeding standards no statement is made as to the amount or kind of mineral matter required by the different classes of animals, the supposition being that a ration which provides the proper amount of protein and other nutrients will also furnish an adequate supply of mineral matter. We have already seen that in some cases, especially with the pig, the mineral supply may be deficient in amount or unbalanced in character in rations which meet the ordinary standards. (**96-101, 119**) In computing rations the special requirements of the various classes of animals, as set forth in the preceding chapters, should therefore be kept clearly in mind.

162. Palatability.—As has already been pointed out (**56**), the palatability of the ration is an important factor in stimulating digestion and in inducing the animal to consume heavy rations. The wise feeder will utilize feeds of low palatability chiefly for such animals as are being merely maintained, and will feed growing and fattening animals, milch cows, and horses at hard work rations made up, for the most part at least, of well-liked feeds. Some concentrates, such as malt sprouts and dried distillers' grains, which may not be relished when fed alone, are entirely satisfactory if given in mixture with other better-liked feeds. Similarly, such roughages as straw and marsh hay, which are of low palatability, may be given in limited amount even to animals fed for production, a practice widely followed by European farmers. While the maximum gains may be made on rations composed entirely of exceedingly palatable feeds, it should be remembered that one of the chief functions of our useful domestic animals is to consume and convert into useful products materials which would otherwise be wasted. (**2**)

163. Variety of feeds.—Skilled feeders usually maintain that a ration composed of a variety of feeds will give better results than when a smaller number are employed, even tho the latter ration supplies the proper amount of protein, carbohydrates, and fat. From the discussions in the preceding chapters, in which it has been pointed out that the protein furnished by certain feeds is unbalanced in composition, it is evident that a larger variety of feeds may, by the law of chance, furnish a better balanced mixture of proteins than 1 or 2 feeds alone. (**94, 118**) With these facts in mind it would seem wise, in choosing supplements for a ration low in protein, to select those which will supply protein from different sources. For example, it is injudicious, if other supplements are equally available, to use corn by-products, such as corn gluten feed or gluten meal, in balancing the ration of pigs otherwise fed corn only. With dairy cows, especially in the case of high-producing animals being forced on official test, skilled feeders place emphasis on having variety in the ration, tho this does not imply changes in the ration from day to day. Indeed, sudden changes in kinds of feed are to be avoided. At least with horses and fattening animals, the advantage of a large variety of feeds in the ration does not seem to have been proven, provided the simple ration furnishes the proper amount and kind of nutrients. For example, oats and timothy hay for the horse, and corn and skim milk for the fattening pig, furnish rations which can scarcely be improved from the standpoint of production and health, tho other combinations may perhaps be cheaper.

164. Cost of the ration.—The most important factor of all, for the farmer who must depend on the profits from his stock for his income, is the cost of the ration. In securing a ration which provides the nutrients called for by the standards and meets the other conditions previously discussed, lies a great opportunity for exercising foresight and business judgment on every farm where animals are fed. The wise farmer-feeder will consider the nutrient requirements of his animals in planning his crop rotations. Thru the use of grain from corn or the sorghums, legume hay, and such cheap succulence as silage from corn or the sorghums, it is possible in most sections of the country to go far toward solving the problem of providing a well-balanced, economical ration.

165. Feeding standards only approximate guides.—In a previous chapter it has been shown that the composition of a given feeding-stuff is not fixed, but may be materially influenced by such factors as climate, stage of maturity when harvested, etc. (**81**) Individual animals also differ from one another in their ability to digest and utilize their feed. (**85-6**) It should, therefore, be borne in mind that tables of digestible nutrients and likewise feeding standards are but averages and approximations—something far different from the multiplication table or a table of logarithms. They should be regarded as reasonable approximations to great vital facts and principles in the feeding of farm animals.

The allowance of protein set forth in the standards is the minimum amount recommended by the scientists for the best results. Where protein-rich feeds are lower in price than those carbonaceous in character, as alfalfa in the alfalfa districts of the West and cottonseed meal in the cotton-belt, it is often economical to furnish more protein than is called for by the standards. Except in the case of very young animals, it is, however, probably not advisable to feed rations having a nutritive ratio narrower than 1:4 or 1:4.5. Where protein-rich feeds are high in price it may be economical to feed a wider ration than advised by the standards, tho it is rarely wise to depart far from them.

166. Limitations of balanced rations.—That other factors than the total amount of protein, carbohydrates, fat, and net energy are of importance in determining the value of rations, is shown in a striking manner by Hart, McCollum, Steenbock, and Humphrey[10] at the Wisconsin Station in experiments which are still in progress. In these trials, which have so far covered 8 years, heifers were fed to maturity on rations from a single plant source, which furnished the full amount of nutrients and of net energy called for by the standards. One lot was fed wholly on products from the corn plant alone, including corn stover, corn grain, and gluten feed; a second, a ration from the wheat plant, including wheat straw, wheat grain, and wheat gluten; a third, a similar ration from the oat plant; and a fourth, a combination ration from all 3 plants. The effects of these restricted rations were not especially marked until the animals underwent the strain of reproduction. Then it became evident that the wheat ration was strikingly deficient in some hidden way, the cows in this lot invariably bringing forth either dead or weak, undersized offspring. On the other hand, the calves from the corn-fed mothers were always strong and healthy. Contrary to what many practical feeders would expect, the ration from the corn, wheat, and oat plants combined, altho supplying a much greater variety, proved inferior to the ration from the corn plant alone. Apparently the bad results from the wheat ration are due to an unbalanced protein supply (**94-5, 118, 150**), to a deficiency of mineral matter (**96-100, 119**), and perhaps to other causes not yet ascertained. (**104**) It was found that when alfalfa hay replaced part of the wheat straw in the wheat ration normal calves were produced.

[10] Wis. Res. Bul. 17; Rpts., 1912, 1914.

It should not be concluded from these trials that feeding stuffs from the wheat plant are dangerous feeds or that feeding standards are of little value. They merely emphasize the fact that, in forming rations, we must consider not only the physiological action of the individual feeds, but also the effect of the combination as it is found in the ration. With this in view the practical feeder and the student alike will attach especial importance to the summaries presented in Part III of the results actually secured with all classes of animals when fed many different rations.

167. Hints on formulating rations.—In computing rations one should have in mind the approximate amount of roughage and concentrates required per 1000 lbs. live weight by the various classes of animals. As will be shown in the experiments reviewed in Part III, the proportion of concentrates and roughages depends first of all on how much it is desired to force the animal; for example, when it is desired to fatten animals rapidly the allowance of concentrates must be considerably larger than when they are fattened more slowly and thru a longer period. In a similar manner, the horse at hard work should be given more grain and less roughage than the horse working but little. In general, the following summary will be helpful as a guide in computing rations:

Mature idle horses and mature cattle and sheep being maintained at constant weight may be fed chiefly or entirely on roughage, unless it is of poor quality, when some grain must be used.

Horses at work should be given 2 to 3 lbs. of feed (roughages and concentrates combined) daily per 100 lbs. live weight, the allowance of concentrates ranging from 10 to 18 lbs., depending on the severity of the work.

Dairy cows in milk should be fed about 2 lbs. of dry roughage or 1 lb. of dry roughage and 3 lbs. of silage daily per 100 lbs. live weight, with sufficient concentrates in addition to bring the nutrients up to the standard.

Fattening steers should receive 2.1 lbs. or more of concentrates and dry roughage (or the equivalent in silage) daily per 100 lbs. live weight, the allowance of concentrates ranging from less than 1 lb. to 1.7 lbs. or more, depending on the rate of gain desired and the character of the roughage.

Fattening lambs will consume about 1.4 lbs. of dry roughage daily when fed all the grain they will eat, and up to 2.3 lbs. or over when the grain allowance is restricted. Silage may replace a corresponding amount of dry matter in dry roughage.

Pigs can make but limited use of dry roughage, except in the case of brood sows not suckling young.

168. Maintenance ration for steers.—Having discussed the general factors which should be considered in computing rations for farm animals, let us now calculate the feed required, according to the Wolff-Lehmann standard, to maintain a 1000-lb. ox at rest in his stall when neither gaining nor losing in weight. Since it has been shown that mature animals can be maintained largely on roughages(**91**), let us see how nearly field-cured corn stover and oat straw will meet the requirements. Since the standard calls for 18 lbs. of dry matter we will first try quantities of these feeds which supply slightly less than this amount.

If for the trial ration it is decided to feed 10 lbs. of corn stover and 10 lbs. of oat straw for roughage, then, using the values for digestible nutrients given in Appendix Table III, the calculations for dry matter and digestible nutrients would be as given below:

Corn stover, field-cured

	In 100 pounds	In 10 pounds
Dry matter	59.0÷100×10=	5.90
Crude protein	1.4÷100×10=	0.14
Carbohydrates	31.1÷100×10=	3.11
Fat	0.6÷100×10=	0.06

Oat straw

	In 100 pounds	In 10 pounds
Dry matter	88.5÷100×10=	8.85
Crude protein	1.0÷100×10=	0.10
Carbohydrates	42.6÷100×10=	4.26
Fat	0.9÷100×10=	0.09

Arranging these results in tabular form, we have:

First trial ration for maintaining 1000-lb. ox at rest

Feeding stuffs	Dry matter	Digestible nutrients			Nutritive ratio
		Crude protein	Carbo-hydrates	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.	
Corn stover, 10 lbs.	5.90	0.14	3.11	0.06	....
Oat straw, 10 lbs.	8.85	0.10	4.26	0.09	....
First trial ration	14.75	0.24	7.37	0.15	1 : 32.2
Wolff-Lehmann standard	18.00	0.70	8.00	0.10	1 : 11.8
Excess or deficit	−3.25	−0.46	−0.63	+0.05	....

This trial ration contains only about one-third the digestible crude protein called for and also falls below the standard in dry matter and carbohydrates. To improve it let us substitute 5 lbs. of clover hay, which is high in protein, for the same weight of corn stover, and add 0.5 lb. of protein-rich linseed meal. We then have:

Second trial ration for maintaining 1000-lb. ox at rest

Feeding stuffs	Dry matter	Digestible nutrients			Nutritive ratio
		Crude protein	Carbo-hydrates	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.	
Clover hay, 5 lbs.	4.36	0.38	1.96	0.09	....
Corn stover, 5 lbs.	2.95	0.07	1.56	0.03	....
Oat straw, 10 lbs.	8.85	0.10	4.26	0.09	....
Linseed meal, 0.5 lb.	0.45	0.15	0.16	0.03	....
Second trial ration	16.61	0.70	7.94	0.24	1 : 12.1
Wolff-Lehmann standard	18.00	0.70	8.00	0.10	1 : 11.8
Excess or deficit	−1.39	0.0	−0.06	+0.14	....

This ration closely approaches the standard. It falls below by more than 1 lb. of dry matter, but this deficiency is unimportant. Dry matter is only an indication of the bulk or volume of the ration, and may vary greatly with different feeds and animals without affecting results. The excess of fat will more than make up the trifling deficit of carbohydrates, for fat has 2.25 times the heat value of carbohydrates. The nutritive ratio of this ration is 1:12.1, which is very close to that called for by the standard. From this we learn that 5 lbs. of clover hay, 5 lbs. of field-cured corn stover, 10 lbs. of oat straw, and 0.5 lb. of linseed meal should furnish sufficient nutrients to maintain a 1000-lb. ox for 24 hours at rest when neither gaining nor losing in weight.

It is practically impossible, as well as useless, to attempt to formulate rations that will exactly agree with the standard in all nutrients. The Wolff-Lehmann standards were devised to cover the common systems of feeding in Europe, where some straw or other low grade roughage is commonly included in rations for horses and ruminants. When only such high grade roughages as silage and legume hay are used, rations which supply enough digestible nutrients will fall below the standard requirement in dry matter. Provided the ration furnishes bulk sufficient to distend the digestive tract properly, no further attention need be paid to such a deficit of dry matter. American rations will usually furnish an excess of fat over the standard, in which case the carbohydrates may fall somewhat below the standard as an offset, it being borne in mind that 1 lb. of fat will replace 2.25 lbs. of carbohydrates. (**70**)

Several devices and expedients have been offered to shorten the work of calculating rations. Willard of the Kansas Station[11] presents a system based on alligation, while Spillman of the Washington Station[12] and Jeffers[13] have invented ingenious mechanical computers. It seems best in this work to show how to perform the calculations in the simplest and most direct manner. Thru such drill the student will become familiar with the quantity and proportion of the several nutrients in common feeding-stuffs and the amount of these required by farm animals according to the standards. The whole matter is less difficult and no more fatiguing than the simpler arithmetical operations of the secondary schools, while the benefits should richly compensate the agricultural student for the time and effort.

IV. Kellner's Starch Values and Feeding Standards

We have already pointed out that the careful and laborious investigations conducted by Kellner and Zuntz by means of a modern respiration apparatus and by Armsby by means of a respiration calorimeter show that the total quantity of digestible nutrients in a feeding-stuff is not necessarily the true measure of its feeding value, as is assumed in

[11] Kan. Bul. 115; Cyclopedia of Am. Agr., Bailey, Vol. III, p. 103.

[12] Wash. Bul. 48.

[13] H. W. Jeffers, Plainsboro, N. J.

the Wolff-Lehmann feeding standards. These investigators have found that, to determine the true net value of any given feeding-stuff to the animal, it is necessary to deduct the energy expended in the work of mastication, digestion, and assimilation from the total available energy furnished by the digestible nutrients in the feeding-stuff. (78-80)

169. Kellner's starch values.—As a result of his investigations Kellner formulated feeding standards based on what he called "starch values."[14] He found that on the average 1 lb. of digestible starch fed to the ox in excess of maintenance requirements produced 0.248 lb. of body fat. (129) Taking 1 lb. of digestible starch as his unit, he gives the following starch values for the digestible nutrients in feeding-stuffs, based on the amount of body fat these several pure nutrients will form if fed to the ox:

In 1 lb. of digestible	Starch Value Lbs.
Protein	0.94
Nitrogen-free extract and fiber	1.00
Fat in roughage, chaff, roots, etc.	1.61
Fat in cereals, factory and mill by-products	2.12
Fat in oil-bearing seeds and oil meal	2.41

Kellner further found that the net nutritive value of certain concentrates, such as grains and seeds, oil cake, roots, and slaughter-house byproducts was about the same as that obtained when the several pure nutrients in them were fed separately. Tho the exact starch value of each such feed can be determined only by careful experimentation, the approximate value may be computed from amounts of each class of digestible nutrients the feed furnishes. For example, the approximate starch value of dent corn can be found as follows, using the content of digestible nutrients as given in Appendix Table III.

Calculation of approximate starch value of dent corn

	Digestible nutrients in 100 lbs. Lbs.		Factor		Starch value Lbs.
Digestible protein	7.5	×	0.94	=	7.05
Nitrogen-free extract and fiber	67.8	×	1.00	=	67.80
Fat	4.6	×	2.12	=	9.75
Total	79.9				84.60

The approximate starch value of dent corn is thus about 84.6 lbs. It is not possible to compute the starch values of feeds high in fiber with any degree of exactness. From the few typical feeds which he actually studied in respiration experiments, Kellner found that with such feeds it was necessary to make deductions from the starch values computed as before, ranging all the way from 5 to 30 per ct. with mill and factory by-products, and from 50 to 70 per ct. with straw, to get their true starch values. By making arbitrary deductions in this manner he com-

[14]Landw. Kal., 1909, I, pp. 103–119; Ernähr. Landw. Nutztiere, 1907.

puted the starch values for a long list of feeding-stuffs. Owing to the great amount of labor involved, he determined the starch values by actual experiment for only about a dozen feeds. The others must, therefore, be regarded as approximations, which are helpful until the true net values of such feeds have been found. Moreover, he ascertained the starch values of these feeds only when they were fed in a moderate ration to the mature ox during the first stages of fattening. Eckles of the Missouri Station[15] has found these values too low when applied to the dairy cow, and Woods[16] of Cambridge University, England, has shown that they are too high for the ox fed a heavy fattening ration. Concerning the starch values for other classes of animals we know little or nothing.

170. Kellner's feeding standards.—Kellner has formulated feeding standards for the various classes of animals in which the requirements are expressed in dry matter, digestible protein, and starch values. For example, his standard for the maintenance of the mature steer per 1000 lbs. live weight calls for 15 to 21 lbs. dry matter, 0.6 to 0.8 lb. digestible protein, and 6.0 lbs. starch values.

The Kellner tables of starch values and his feeding standards are not here given in detail, but instead Armsby's tables of net energy values and of feeding standards, which are similar and which are chiefly used in this country by those desiring to compute rations according to the net energy system.

V. The Armsby Energy Values and Feeding Standards

171. The Armsby energy values.—With the first and only respiration calorimeter used in the study of farm animals in America, Armsby of the Pennsylvania Station[17] has determined the net energy values for 8 typical feeds and 2 concentrate mixtures. He has used these values and the starch values obtained by Kellner as the basis for estimating the losses of energy in the mastication, digestion, and assimilation of other feeds. By special permission of the authors of this volume, he has then computed from the average content of digestible nutrients of various feeds shown in Appendix Table III, the net energy values of the most important American feeds. Some of these values are given in the table on the next page.

The last column of the table does not show the total energy in the digestible portion of 100 lbs. of the various feeding stuffs, but only the net energy, i. e., that portion which is finally available to the animal

[15] Mo. Res. Bul. 7.

[16] Jour. Agr. Sci., 5, 1914, p. 248.

[17] U. S. Dept. Agr., Bur. Anim. Indus., Buls. 51, 74, 101; Farmer's Bul. 346; Jour. Agr. Res., 3, 1915, p. 435; Penn. Bul. 142.

after deducting the losses occurring thru mastication, digestion and assimilation. He expresses the net energy in therms in place of Kellner's starch values (75). The second column gives the digestible crude protein, as shown in Appendix Table III of this book, and the third column the digestible true protein as estimated by Armsby from the crude protein and Kellner's data.

Net energy values in 100 lbs. of various feeding stuffs

Feeding stuffs	Total dry matter	Digestible crude protein	Digestible protein	Net energy value
Grains	Lbs.	Lbs.	Lbs.	Therms
Barley	90.7	9.0	8.3	89.94
Corn, dent	89.5	7.5	7.0	89.16
Corn-and-cob meal	89.6	6.1	5.7	75.80
Oats	90.8	9.7	8.7	67.56
Peas, field	90.8	19.0	16.6	78.72
Rye	90.6	9.9	9.0	93.71
Wheat	89.8	9.2	8.1	91.82
By-products				
Brewers' grains, dried	92.5	21.5	20.2	53.38
Brewers' grains, wet	24.1	4.6	4.4	14.53
Buckwheat middlings	88.0	24.6	20.8	72.19
Cottonseed meal, choice	92.5	37.0	35.4	93.46
Distillers' grains, dried from corn	93.4	22.4	18.3	85.08
Distillers' grains, dried, from rye	92.8	13.6	11.1	56.01
Gluten feed	91.3	21.6	20.1	80.72
Gluten meal	90.9	30.2	28.1	84.15
Linseed meal, old process	90.9	30.2	28.5	88.91
Malt sprouts	92.4	20.3	12.5	72.72
Rye bran	88.6	12.2	10.5	79.35
Skim milk, centrifugal	9.9	3.6	3.6	14.31
Sugar beet pulp, wet	9.3	0.5	0.5	8.99
Tankage, over 60 per cent protein	92.6	58.7	55.6	93.04
Wheat bran	89.9	12.5	10.8	53.00
Wheat middlings, flour	89.3	15.7	14.0	75.02
Wheat middlings, standard	89.6	13.4	12.0	59.10
Dried roughage				
Alfalfa hay	91.4	10.6	7.1	34.23
Clover, crimson	89.4	9.7	6.9	36.21
Clover, red	87.1	7.6	4.9	38.68
Cowpea hay	90.3	13.1	9.2	37.59
Corn fodder, medium dry	81.7	3.0	2.3	43.94
Corn stover, medium dry	81.0	2.1	1.6	31.62
Millet hay, Hungarian	85.7	5.0	3.9	46.96
Mixed timothy and clover hay	87.8	5.3	3.2	41.07
Oat straw	88.5	1.0	0.8	34.81
Red top hay	90.2	4.6	3.9	51.22
Rye straw	92.9	0.7	0.5	17.59
Soybean hay	91.4	11.7	8.8	44.03
Timothy hay	88.4	3.0	2.2	43.02
Wheat straw	91.6	0.7	0.3	7.22
Green fodder and silage				
Alfalfa, in bloom	25.9	3.3	1.8	11.50
Clover, crimson	17.4	2.3	1.6	10.83
Clover, red	26.2	2.7	1.7	15.87
Corn fodder, dent	23.1	1.0	0.8	14.60
Corn silage, well matured	26.3	1.1	0.6	15.90
Millet, Hungarian	27.6	1.9	1.1	17.24
Oat fodder	26.1	2.3	2.0	14.06
Rape	16.7	2.6	1.7	13.07
Timothy, in bloom	32.1	1.3	0.8	18.89
Roots and tubers				
Carrots	11.7	0.9	0.5	9.21
Mangels	9.4	0.8	0.1	5.68
Potatoes	21.2	1.1	0.1	18.27
Rutabagas	10.9	1.0	0.3	8.46
Turnips	9.5	1.0	0.4	6.16

Of the feeds listed, rye has the highest net energy value, 93.71 therms per 100 lbs. Due to the large amount of fiber contained in the hulls, the net energy value of oats is only 67.56 therms per 100 lbs. The dry roughages furnish much less net energy than the concentrates, wheat straw having a value of only 7.22 therms per 100 lbs.

172. The Armsby standards for maintenance.—The following table by Armsby sets forth the maintenance requirements of horses, cattle, and sheep, no table having yet been formulated for swine:

Armsby's maintenance standards for horses, cattle, and sheep

Live weight	Horses		Cattle		Sheep		
	Digestible protein	Energy value	Digestible protein	Energy value	Live weight	Digestible protein	Energy value
Lbs.	Lbs.	Therms	Lbs.	Therms	Lbs.	Lbs.	Therms
150	0.30	2.00	0.15	1.70	20	0.023	0.30
250	0.40	2.80	0.20	2.40	40	0.05	0.54
500	0.60	4.40	0.30	3.80	60	0.07	0.71
750	0.80	5.80	0.40	4.95	80	0.09	0.87
1000	1.00	7.00	0.50	6.00	100	0.10	1.00
1250	1.20	8.15	0.60	7.00	120	0.11	1.13
1500	1.30	9.20	0.65	7.90	140	0.13	1.25

The table shows that a young horse weighing 500 lbs., if neither gaining nor losing in weight, would require for its daily support 0.60 lb. of digestible protein and 4.40 therms of net digestible matter, the latter including the 0.60 lb. of digestible protein. When this growing horse reaches 1000 lbs., there is required for its maintenance 1 lb. of digestible protein and 7 therms of net digestible matter. Tho it has doubled in weight, the food requirement has not likewise doubled. When the horse reaches the weight of 1500 lbs., there is required a further increase of only 0.3 lb. of protein and 2.20 therms of net energy. This is due to the fact, already pointed out (**91**), that the maintenance requirement depends not on body weight but upon body surface. In recognizing this fact, Armsby has made an important advance over the Wolff-Lehmann standards.

173. Standards for growing animals.—In the table which follows, Armsby sets forth the digestible protein and net energy requirements of growing cattle and sheep, no data as yet having been given for horses and swine. The figures include the maintenance requirements.

The Armsby standards for growing cattle and sheep

Age	Cattle			Sheep		
	Live weight	Digestible protein	Net energy value	Live weight	Digestible protein	Net energy value
Months	Lbs.	Lbs.	Therms	Lbs.	Lbs.	Therms
3	275	1.10	5.0	...	....	....
6	425	1.30	6.0	70	0.30	1.30
9	....	....	...	90	0.25	1.40
12	650	1.65	7.0	110	0.23	1.40
15	....	....	...	130	0.23	1.50
18	850	1.70	7.5	145	0.22	1.60
24	1000	1.75	8.0	...	....	....
30	1100	1.65	8.0	...	....	....

The table shows that a 3-months-old calf, weighing 275 lbs., requires 1.10 lbs. of digestible protein and 5 therms of net energy value, the latter including the 1.10 lbs. protein. When the calf has grown to 1100 lbs., or quadrupled in weight, it requires but 0.55 lb. more protein and 3 more therms than before. This relative lessening in feed requirement is due to the fact that the larger animal requires relatively less for maintenance, as explained elsewhere. (**91**) For the 1000-lb. steer Armsby allows 1.75 lbs. of digestible protein, and but 1.65 lbs., or 0.10 lb. less, for the same animal when weighing 1,100 lbs. This is because at the higher weight the steer has practically ceased muscular growth and therefore needs less protein than earlier in life. A comparison of the maintenance and growth requirements of animals, as here set forth, reveals the fact that a large portion of all the feed the animal consumes is used for the support of the body, and that the additional requirements for growth are not relatively large.

174. Milch cows, fattening steers, and other animals.—Armsby supplements the foregoing partial standards with the following:

1. For milk production, add to the maintenance standard 0.05 lb. of digestible protein and 0.3 therm for each pound of 4 per ct. milk to be produced.

2. For 2- to 3-year-old fattening cattle, add 3.5 therms to the standard for growth for each pound of gain to be made.

For the milch cow Armsby provides additional food, both protein and therms, as noted in the foregoing, because milk is rich in complex protein compounds, and also contains carbohydrates and fat. Furthermore, the cow is usually growing a calf. Armsby holds that, after providing the protein set forth in the ration for growth, the steer will fatten satisfactorily without any additional protein, provided there are supplied sufficient carbohydrates and fat to meet the standard. It should be borne in mind that to prevent a depression of the digestibility of the ration on account of too large a proportion of carbohydrates, at least 1 lb. of digestible protein should be supplied in the ration for each 8 to 10 lbs. of carbohydrates and fat. (**84**) As a rough guide to the amount of dry matter to be fed, Armsby recommends that:

1. A 1000-lb. ruminant should receive 20 to 30 lbs., or an average of 25 lbs., dry matter per day.

2. The horse should receive somewhat less dry matter than ruminants.

For work horses he recommends Kellner's standard which is based upon the extensive work of Zuntz. This standard, converted from starch values to therms, is given in a later chapter. (**456**) Armsby has formulated no standards for fattening sheep or lambs, for growing horses, or for pigs.

175. Fattening lambs.—Bull and Emmett of the Illinois Station[18] have made a critical and comprehensive study of the American investigations in fattening lambs, covering trials in which 265 lots of lambs, aggregating 5,127 animals, were fed. From the results secured in these trials, they give the following as the approximate minimum requirements of digestible crude protein and net energy per 1000 lbs. live weight.

[18] Ill. Bul. 166.

Bull-Emmett standards for fattening lambs

Weight	Per 1000 lbs. live weight	
	Digestible crude protein	Net energy value
	Lbs.	Therms
Lambs weighing 50-70 lbs.	3.1–3.3	17–19
Lambs weighing 70-90 lbs.	2.5–2.8	18–20
Lambs weighing 90-110 lbs.	2.2–2.4	17–20
Lambs weighing 110-150 lbs.	1.4–1.9	16–19

It will be noted that the requirements for protein are expressed in terms of crude protein instead of true protein, as in the Armsby standards. Bull and Emmett state that the figures for lambs weighing 110 to 150 lbs. are only approximations, owing to the small amount of data available for animals of these weights. It will be noted that as the lambs become more mature the amount of protein required per 1000 lbs. live weight grows less.

176. Ration for maintaining the steer.—To illustrate the method of using the Armsby standards and table of net energy values, let us compute a ration for maintaing a mature steer weighing 1000 lbs., when neither gaining nor losing weight, assuming that there are available corn stover, oat straw, dent corn, and cottonseed meal. According to the standard, an animal of this weight requires 0.5 lb. digestible protein and 6.0 therms of net energy. As corn stover and oat straw are much cheaper than the concentrates, let us first see how nearly a ration of these roughages alone will meet the requirements. Suppose that we select for a trial ration 10 lbs. of corn stover and 8 lbs. of oat straw. The calculations will then be as follows:

Calculations for trial ration for maintaining 1000-lb. steer

	Corn stover In 100 lbs.	In 10 lbs.		Oat straw In 100 lbs.	In 8 lbs.
Dry matter	81.0 ÷ 100 × 10	=8.10	Dry matter	88.5 ÷ 100 × 8	=7.08
Dig. protein	1.6 ÷ 100 × 10	=0.16	Dig. protein	0.8 ÷ 100 × 8	=0.06
Net energy	31.62 ÷ 100 × 10	=3.16	Net energy	34.81 ÷ 100 × 8	=2.78

First trial ration for maintaining 1000-lb. steer

Feeding stuffs	Total dry matter	Digestible protein	Net energy value
	Lbs.	Lbs.	Therms
Corn stover, 10 lbs.	8.10	0.16	3.16
Oat Straw, 8 lbs.	7.08	0.06	2.78
First trial ration	15.18	0.22	5.94
Standard requirement	....	0.50	6.00
Excess or deficit	....	—0.28	—0.06

This ration furnishes enough net energy but is deficient in digestible protein. Corn, which is high in net energy but low in protein, will not improve the ration, while cottonseed meal, which is rich in protein, will make up the deficiency. Let us therefore substitute 1 lb. of choice cottonseed meal for 2 lbs. of oat straw. We then have:

Second trial ration for maintaining 1000-lb. steer.

Feeding stuffs	Total dry matter	Digestible protein	Net energy value
	Lbs.	Lbs.	Therms
Corn stover, 10 lbs........	8.10	0.16	3.16
Oat straw, 6 lbs...........	5.31	0.05	2.09
Cottonseed meal, 1.0 lb....	0.92	0.35	0.93
Second trial ration........	14.33	0.56	6.18
Standard requirement.....	....	.50	6.00
Excess or deficit..........	....	+0.06	+0.18

This ration agrees closely with the standard in digestible protein and net energy value. Thus, according to the Armsby standard, a satisfactory ration for maintaining a 1000-lb. steer may be composed of 10 lbs. corn stover, 6 lbs. oat straw and 1 lb. choice cottonseed meal.

177. Discussion of the net energy systems.—The determination of the net energy values of feeding-stuffs is an important advancement in our knowledge of the values of different feeds for productive purposes. Owing to the immense amount of labor involved in each such determination, data of this kind can be secured but slowly. In 14 years Armsby has been able to study only 10 feeds, several determinations of course having been made upon each. The actual net energy value of only 22 feeding-stuffs has thus been determined by both Kellner and Armsby. While these values are helpful in estimating the probable net energy values of other feeds not yet tested, such computed results are but approximations. For example, in his earlier table of energy values, Armsby gave a net energy value of 33.56 therms for timothy hay containing 86.8 per ct. dry matter. This value was computed from Kellner's data. After conducting several respiration experiments in which the actual net value was determined, Armsby found that timothy hay containing the same amount of dry matter had a net energy value of 42.20 therms, or 25.7 per ct. more than his former figure. Even for the feeds on which experiments have been conducted, the values are far from exact. Not only do different samples of a given feeding-stuff vary in composition (81), but the trials show that the ability to utilize feed, even by animals of the same kind, age, and condition, may vary to a greater or less extent. Moreover, both Kellner and Armsby have practically worked only with the steer, and the extent to which the values thus secured apply to other classes of animals is still a question. (169) Zuntz,[19] who has conducted extensive studies on the utilization of different feeding-stuffs, states that with the horse and pig only a small portion of the starch in feeds ferments in the

[19]Inter. Inst. Agr., Monthly Bul., 5, 1914, No. 4, pp. 435, 446.

digestive tract. On the other hand, in cattle upwards of 10 per ct. of the heat value of the digested food is lost in methane gas and about 7 per ct. is wasted, so far as productive purposes are concerned, in the heat produced in the fermentations. (**79-80**) Accordingly, with horses and pigs starch will have a higher value compared with fat than in the case of ruminants. Zuntz concludes: "If we apply to pigs or horses the same starch values for a fat food, such as an oil seed, as was determined by Kellner, we commit a notable error. . . . We must no longer attribute to a certain food the same nutritive value under all circumstances, as has hitherto been done. We must rather find out in what combination the nutritive value of a food proves the most advantageous." We must thus regard the present net energy values of feeding stuffs, not as exact measures of their value for all classes of animals, but as approximations which are most helpful in teaching great principles in the feeding of live stock.

From the foregoing discussion the wise feeder will see the importance of studying carefully the results actually secured with different combinatious of feed when fed to the various classes of animals, as presented in detail in the respective chapters of Part III.

VI. The Scandinavian Feed-Unit System

A system of feed equivalents, based mainly on the extensive experiments with milch cows and swine by Fjord and his successors at the Copenhagen Station, has been adopted in Denmark and other Scandinavian countries, especially by the cow-testing associations, for measuring the relative production economy of cows. This system is extensively used with cows, occasionally with pigs, and rarely with other animals. It has great merit, especially in co-operative efforts to improve dairy cattle and their feeding—lines in which the Scandinavian farmers are leaders.

178. The feed unit.—The feed unit of the Danish associations is 1 lb. of standard grain feed, such as corn and barley, or their equivalents in feeding value. In Sweden it is one kilo (2.2 lbs.) of mixed concentrates or their equivalent. All feeding-stuffs are reduced to this standard in calculating the feed consumption of the animal. The amounts of various feeds required to equal 1 feed unit are shown in the following table.

The table shows that corn, wheat, rye, barley, hominy feed, the dry matter in roots, etc., are all considered to have about the same value for the dairy cow, 1 lb. equaling 1 feed unit. On this basis it requires 1.1 lbs. of wheat bran or oats, or 1.5 to 3 lbs. of alfalfa or clover hay to equal 1 unit. Cottonseed meal, linseed meal, dried distillers' grains, gluten feed, and soybeans are rated at a higher value than the same weight of corn or wheat, less than a pound of these concentrates being required for a feed unit.

*Amount of different feeds required to equal one feed unit**

Feed	Feed required to equal 1 unit	
	Average	Range
For dairy cows	Lbs.	Lbs.
Concentrates		
Corn, wheat, rye, barley, hominy feed, dried brewers' grains, wheat middlings, oat shorts, peas, molasses beet pulp, dry matter in roots	1.0	....
Cottonseed meal	0.8	....
Oil meal, dried distillers' grains, gluten feed, soy beans	0.9	....
Wheat bran, oats, dried beet pulp, barley feed, malt sprouts	1.1	....
Alfalfa meal, alfalfa molasses feeds	1.2	....
Hay and straw		
Alfalfa hay, clover hay	2.0	1.5–3.0
Mixed hay, oat hay, oat and pea hay, barley and pea hay, red top hay	2.5	2.0–3.0
Timothy hay, prairie hay, sorghum hay	3.0	2.5–3.5
Corn stover, stalks or fodder, marsh hay, cut straw	4.0	3.5–6.0
Soiling crops, silage and other succulent feeds		
Green alfalfa	7.0	6.0–8.0
Green corn, sorghum, clover, peas and oats, cannery refuse	8.0	7.0–10.0
Alfalfa silage	5.0	....
Corn silage, pea vine silage	6.0	5.0–7.0
Wet brewers' grains	4.0	....
Potatoes, skim milk, buttermilk	6.0	....
Sugar beets	7.0	....
Carrots	8.0	....
Rutabagas	9.0	8.0–10.0
Field beets, green rape	10.0	....
Sugar beet leaves and tops, whey	12.0	....
Turnips, mangels, fresh beet pulp	12.5	10.0–15.0
The value of pasture is generally placed at 8 to 10 units per day, on the average, varying with kind and condition.		
For pigs		
Indian corn, barley, wheat, oil cakes	1.0	....
Rye, wheat bran	1.4	....
Boiled potatoes	4.0	....
Skim milk	6.0	....
Whey	12.0	....
For horses		
One lb. of Indian corn equals 1 lb. of oats or 1 lb. of dry matter in roots.		

*The values for pigs and horses are those given in the Danish valuation table and those for dairy cows the values as revised by Woll for American feeding stuffs, given in Wis. Cir. 37.

The feed-unit values are not true expressions of net energy, for in this system feeds rich in protein are given a higher value than feeds low in protein which furnish the same amount of net energy. For example, in the feed-unit system, only 0.8 lb. of cottonseed meal or 0.9 lb. of linseed meal is required to equal 1 feed unit. Yet, according to Armsby and Kellner the net energy value of these feeds is lower than that of corn. Again, the energy value of timothy hay is about the same as that of clover or alfalfa hay, but in the feed-unit system timothy hay is rated 50 per ct. below the legume hays. When added to rations deficient in protein, feeds rich in protein will have a higher value than those supplying an equal amount of net energy but which are low in protein. But as has been pointed out (**63, 93**), when the protein supply in the ration is already adequate, any additional amount of this nutrient is broken down in the body, the nitrogenous portion being excreted in the urine, and only the remainder utilized for the formation of the fat and carbohydrates in flesh or milk, for body fuel, or for the production of work. In all such cases protein will have a value corresponding only to the amount of net energy it furnishes. Over large sections of our country protein-rich feeds are cheaper than those high in carbohydrates. In the West with its abundant and cheap alfalfa hay, and in the South with its low-priced cottonseed meal, it is often necessary to add carbonaceous feeds rather than protein-rich concentrates to balance the usual rations. Thus the feed-unit system does not furnish a safe guide by which the farmer can determine the value of feeds under all conditions. The worth of a given feed to him will depend on the other feeding-stuffs with which it is to be combined. In some instances protein-rich feeds will be worth the most, and in others, those which are high in carbohydrates. The feed-unit system has been evolved in a comparatively small region, where similar crops are grown on the different farms and the price of purchased feeds does not vary widely thruout the entire district, hence this difficulty has not arisen there. No arbitrary values for feeding-stuffs, expressed in terms of money or other fixed units, can be devised which will hold good under widely differing conditions.

179. Measuring economy of production in feed units.—The chief value of the feed unit system for dairymen in any given region is that it furnishes a simple means of comparing the feed consumption and the milk and fat production of different cows, as is shown in the following:

If during a month a cow has consumed 240 lbs. of hay, 750 lbs. of silage, 60 lbs. each of barley and ground corn, and 90 lbs. of linseed oil meal, the calculation based on the valuation table would be as follows:

Feed consumed		Lbs. for 1 unit		Feed units
240 lbs. hay	÷	2.5	=	96
750 lbs. silage	÷	6.0	=	125
120 lbs. corn and barley	÷	1.0	=	120
90 lbs. oil meal	÷	0.9	=	100
Total feed units			=	441

It is shown that the cow consumed 441 feed units during the month. If in that time she yielded 850 lbs. of milk, containing 30.6 lbs. of fat, each 100 feed units produced $\frac{850}{4.41} = 193$ lbs. of milk, containing $\frac{30.6}{4.41} =$ 6.9 lbs. butter fat. If the fat brought 30 cents per lb., 100 feed units would return 6.9x\$0.30=\$2.07.

180. The Swedish Test Associations.—In what follows is shown some of the work of the Swedish Test Associations for the year 1906-7. The first table shows the feed units consumed per cow annually in the association having the poorest and the best returns, and the average of 96 associations. The second table shows the production per cow and per 100 feed units consumed.

The first table shows that the association with the poorest record fed each cow on the average 4920 feed units during the year. The association with the highest record fed 5733 units per cow, while the average for 96 associations was 5280 feed units.

Feed units consumed annually per cow in the Swedish Test Associations

	Concentrates			Roughages		Total
	Oil cakes	Bran and grains	Roots, beet pulp	Hay and straw	Soilage and pasture	
Association	Units	Units	Units	Units	Units	Units
Showing poorest returns....	900	581	900	1142	1397	4920
Showing best returns.......	1056	878	1410	1078	1311	5733
Average of 96 associations...	856	708	1166	1256	1294	5280

Average production per cow and per 100 feed units

	Production per cow			Production per 100 units	
	Milk	Butter fat	Butter	Milk	Butter fat
Association	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Showing poorest returns....	6261	200.0	218.0	127.3	4.1
Showing best returns.......	8650	295.2	327.1	150.9	5.1
Average of 96 associations...	7429	239.9	265.3	140.7	4.5

The second table shows that the average cow in the poorest association gave 6261 lbs. of milk, while in the best association she gave 8650 lbs. The herds in the poorest association yielded about 200 lbs. of butter fat per cow, and those in the best over 295 lbs. The best herds produced 1 lb. more butter fat from 100 feed units consumed than did the poorly-fed herds— a difference of over 24 per ct. in favor of the heavier feeding. These results show the manner in which Scandinavians have utilized the feed-unit system for comparing individual cows, herds, and associations to the great betterment of their dairy industry. The same comparisons can be made by means of the Armsby system of net-energy values. Except where the rations fed to different animals vary widely in proportion of concentrates to roughages, a fair comparison may also be made by using the total digestible nutrients in the ration, as given for each feed in Appendix Table III.

181. The feed-unit standard for dairy cows.—Hansson[20] has proposed the following as the requirements for dairy cows according to the feed-unit system:

For maintenance, feed 0.65 lb. digestible protein and 6.6 feed units daily per 1000 lbs. live weight.

For each pound of milk produced add to the maintenance requirement 0.045 to 0.05 lb. digestible protein and 0.33 feed unit.

The requirements of a cow producing any given amount of milk can be readily ascertained by computation.

[20] Kontrolfören, Arbetsfält, 1910.

VII. American Standards for Dairy Cows

182. The Haecker standard.—As the result of long years of intimate study with a high-grade working dairy herd at the Minnesota Station,[21] Haecker has made an important advance in the formulation of rations for the dairy cow. He has shown that the nutrients required for her nourishment should vary not only with the quantity of milk yielded, as is taught in the Wolff-Lehmann, the Kellner, Armsby, and the feed-unit standards, but also with the quality of the product. The allowance of crude protein recommended is also considerably lower than that set forth in the Wolff-Lehmann standard. In his standard Haecker first sets down the total digestible nutrients daily required to maintain the 1000-lb. cow, independent of the milk she produces, as follows: Crude protein 0.7 lb., carbohydrates 7.0 lbs., and fat 0.1 lb.

For each 100 lbs. live weight the cow may exceed or fall below the 1000-lb. standard there is added or subtracted one-tenth of the standard ration.

To this maintenance provision the further allowance set forth in the table is added.

Haecker's feeding standard for the dairy cow

	Daily allowance of digestible nutrients		
	Crude protein	Carbohydrates	Fat
	Lbs.	Lbs.	Lbs.
For support of the 1000-lb. cow	0.700	7.00	0.100
To the allowance for support add:			
For each lb. of 3.0 per ct. milk	0.047	0.20	0.017
For each lb. of 3.5 per ct. milk	0.049	0.22	0.019
For each lb. of 4.0 per ct. milk	0.054	0.24	0.021
For each lb. of 4.5 per ct. milk	0.057	0.26	0.023
For each lb. of 5.0 per ct. milk	0.060	0.28	0.024
For each lb. of 5.5 per ct. milk	0.064	0.30	0.026
For each lb. of 6.0 per ct. milk	0.067	0.32	0.028
For each lb. of 6.5 per ct. milk	0.072	0.34	0.029
For each lb. of 7.0 per ct. milk	0.074	0.36	0.031

The table shows that a cow yielding milk containing 3 per ct. of butter fat should be fed, in addition to the maintenance ration, 0.047 lb. crude protein, 0.20 lb. carbohydrates, and 0.017 lb. fat, all digestible, for each pound of milk she gives. If the milk is richer than 3 per ct. the provision must be greater. Haecker has formulated the requirements for each increase of 0.1 per ct. in the fat content of milk. At least for ordinary herd feeding it is not necessary to refine the calculation of rations to this extent. Hence only a condensed table is here presented.

[21] Minn. Buls. 71, 79, 140.

To illustrate the use of the table there is formulated below the nutrient allowance for a 1100-lb. cow producing 25 lbs. of 4 per ct. milk daily:

Digestible nutrients required daily by a 1100-lb. cow yielding 25 lbs. of 4 per ct. milk

	Crude protein	Carbo-hydrates	Fat
	Lbs.	Lbs.	Lbs.
For maintenance	0.77	7.70	0.11
For 25 lbs. of 4 per cent milk	1.35	6.00	0.52
Total	2.12	13.70	0.63

In the above there is first set down the maintenance allowance for the 1000-lb. cow, increased by one-tenth because this cow weighs 100 lbs. more than the standard; this is 0.77 lb. crude protein, 7.7 lbs. carbohydrates, and 0.11 lb. fat, all digestible. The previous table shows the daily nutrient allowance for each pound of 4 per ct. milk to be 0.054 lb. crude protein, 0.24 lb. carbohydrates, and 0.021 fat, all digestible. Since this cow is yielding 25 lbs. of milk daily, the foregoing numbers multiplied by 25 are placed in the second line of the table. Thus it is shown that the production of 25 lbs. of 4 per ct. milk calls for 1.35 lbs. of crude protein, 6.00 lbs. of carbohydrates, and 0.52 lb. of fat. Adding these nutrients to those for maintenance, we have 2.12 lbs. of protein, 13.7 lbs. of carbohydrates, and 0.63 lb. of fat as the quantity of digestible nutrients required daily to nourish a 1100-lb. cow properly when giving 25 lbs. of 4 per ct. milk daily.

183. The Woll-Humphrey standard.—From studies at the Wisconsin Station[22] Woll and Humphrey have prepared convenient tables showing the feed requirements of cows of different weights and producing various amounts of butter fat per day. To simplify the computation of rations, in these tables the requirements are stated in terms of dry matter, digestible crude protein, and total digestible nutrients, the latter term including the digestible protein, the digestible carbohydrates, and the digestible fat × 2.25. This simplification is in harmony with the uses made of the different nutrients in the animal body, for as we have already learned (**88, 124-9**), carbohydrates and fat in general perform the same functions in the body. Likewise, after there has been supplied the minimum amount of protein needed for the repair of body tissues and the formation of milk protein, any additional amount serves the same purpose as do the carbohydrates and fat. (**88, 128**) The requirements of a 1000-lb. cow according to these tables are shown in the table on the next page. The allowance for maintenance is the same as that prescribed in the Haecker standard. For the 1000-lb. cow yielding 1.0 to 1.25 lbs. of butter fat

[22] Wis. Res. Bul. 13; Bul. 200.

per day the standard calls for a daily allowance of 23.6 lbs. dry matter, 2.11 lbs. of digestible crude protein, and 15.8 lbs. of total digestible matter.

Woll-Humphrey standard for 1000-lb. dairy cow

	Dry matter	Digestible crude protein	Total digestible matter
	Lbs.	Lbs.	Lbs.
Maintenance	12.5	0.70	7.9
Production of butter fat per day:			
Less than 0.5 pound	16.2	1.18	10.6
0.5 to 0.75 pound	18.7	1.49	12.3
0.75 to 1.0 pound	21.1	1.80	14.1
1.0 to 1.25 pounds	23.6	2.11	15.8
1.25 to 1.5 pounds	26.0	2.43	17.6
1.5 to 1.75 pounds	28.5	2.74	19.3
1.75 to 2.0 pounds	30.9	3.05	21.1

This system of expressing the requirements of dairy cows has been found convenient in practice. It is not strictly accurate, however, when applied to milks varying widely in the percentage of fat contained. Haecker's table places the requirements for a pound of butter fat in rich milk considerably lower than for a pound in milk low in fat. For example, for 100 lbs. of 3 per ct. milk there are required 4.7 lbs. protein, 20.0 lbs. carbohydrates, and 1.7 lbs. fat, while for 50 lbs. of 6 per ct. milk, containing the same amount of fat, only 3.3 lbs. protein, 16 lbs. carbohydrates, and 1.4 lbs. fat are required. This is due to the fact that, tho the 6 per ct. milk contains twice as much fat as the 3 per ct. milk, it is not twice as rich in sugar and protein.

184. The Savage standard.—From trials at the New York (Cornell) Station[23] Savage concludes that for maximum production the nutritive ratio of rations for dairy cows should not be wider than 1:6. He has accordingly modified the Haecker standard by increasing the protein requirement per pound of milk by from 18 to 20 per ct. His standard is also simplified by being stated in terms of dry matter, digestible crude protein, and total digestible nutrients (or as Savage terms it "total nutriment"), in the same manner as in the Woll-Humphrey standard. The requirements according to this standard are shown in Article **186**.

185. The Eckles standard.—From experiments at the Missouri Station[24] and from the work of Savage and Armsby, Eckles has formulated a tentative standard according to the Armsby system, showing the requirements of cows producing milk containing various percentages of fat. He points out that these are but approximations, for the following reasons: The digestion coefficients in use, which have been chiefly obtained with steers and sheep, are too high for feeds fed in heavy rations to dairy cows. This is, however, more than offset by the fact that the cow is able to utilize the nutrients she actually digests more efficiently in milk production than the steer or sheep does in formation of flesh. Hence

[23] N. Y. (Cornell) Bul. 323. [24] Mo. Res. Bul. 7.

the net energy values given by Armsby are too low when applied to milk production.

186. Comparison of standards for dairy cows.—In the following table the Haecker, Savage, and Eckles standards are brought together for comparison. Haecker's figures have been converted into total digestible nutrients as in the Savage standard. The Woll-Humphrey standard can not be included for it is not based on the fat content of the milk, as are the others.

Feeding standards for dairy cows compared

	Haecker standard		Savage standard		Eckles standard	
	Diges'ble crude protein	Total digestible nutrients	Diges'ble crude protein	Total digestible nutrients	Diges'ble true protein	Net energy
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Therms
For maintenance of 1000-lb. cow..	0.700	7.925	0.700	7.925	0.500	6.00
To allowance for maintenance add:						
For each lb. of 2.5 per ct. milk....	0.045	0.254	0.053	0.257	.....	....
For each lb. of 3.0 per ct. milk....	0.047	0.284	0.057	0.287	0.050	0.26
For each lb. of 3.5 per ct. milk....	0.049	0.313	0.061	0.319	0.052	0.28
For each lb. of 4.0 per ct. milk....	0.054	0.343	0.065	0.350	0.055	0.30
For each lb. of 4.5 per ct. milk....	0.057	0.372	0.069	0.379	0.058	0.33
For each lb. of 5.0 per ct. milk....	0.060	0.398	0.073	0.405	0.062	0.36
For each lb. of 5.5 per ct. milk....	0.064	0.424	0.077	0.431	0.066	0.40
For each lb. of 6.0 per ct. milk....	0.067	0.451	0.081	0.457	0.070	0.45
For each lb. of 6.5 per ct. milk....	0.072	0.480	0.085	0.484	0.075	0.50
For each lb. of 7.0 per ct. milk....	0.074	0.502	0.089	0.508	.....	....

The Haecker and Savage standards agree in the requirements for maintenance. Savage's digestible crude-protein requirement for production is higher in each case, as already pointed out. In total digestible nutrients he agrees very closely with Haecker. As Eckles' standard is expressed in digestible true protein (not crude protein) and therms, it can not be directly compared with the others. We may, however, compare this standard with the others in the following manner: In such a ration as 20 lbs. clover hay, 4 lbs. corn, and 4 lbs. wheat bran, we would find that about one-third of the total digestible crude protein is in amid form (**11**) and hence not included in Eckles' figure for digestible true protein. With rations including green forage or silage, the proportion of true protein will be still lower. It is evident, then, that were Eckles' figures for protein converted into crude protein they would be even higher than Savage's when applied to ordinary rations. As about 1.1 to 1.2 lbs. total digestible nutrients have a net-energy value of 1 therm in the ordinary rations used for milk production, it will be found on computation that Eckles' standard calls for about the same amount of total nutrients as the others for milk low in fat, but up to one-fifth more for milk high in fat.

From the foregoing we may conclude that when protein-rich feeds are high in price compared with those low in protein, it will usually be economical to feed no more protein than is called for by the Haecker standard, at least to cows of average production. On the other hand, when protein-rich feeds are comparatively cheap the dairyman may well feed as heavy an allowance as Savage and Eckles recommend. Even these amounts are lower than called for in the original Wolff-Lehmann standards. (**156**) The skilled dairyman will adapt the amount of concentrates fed to the productive ability of each cow, not compounding a different ration for each animal, but will balance the ration for the average of the herd and then feed the cows as much roughage as they will consume and concentrates in proportion to the milk or butter fat produced by the several cows, as is explained in a later chapter. (**661**)

VIII. Modified Wolff-Lehmann Standards

187. Methods of computing rations compared.—In this chapter it has been pointed out that the valuation of feeding stuffs for productive purposes, on the basis of their net energy content, is theoretically more accurate than the Wolff-Lehmann method of comparing them in terms of the digestible nutrients they furnish. Unfortunately, the net-energy values have actually been determined for but a few feeds, and with these only for the fattening ox. For other feeds and other classes of animals, the values which may be computed are but approximations. On the other hand, during the last half-century scores of thousands of analyses of feeding stuffs have been made, as shown in Appendix Table I, and large numbers of digestion experiments have been conducted in which the coefficients of digestibility have been determined, as given in Appendix Table II. Thus the values for digestible nutrients in the various feeding-stuffs, given in Table III, rest on a reasonably secure basis, tho we must remember that different kinds of animals digest somewhat different percentages of feeds, especially of roughages. (**85**)

The value of a concentrate and of a roughage for productive purposes can not be compared on the basis of the digestible nutrients each furnishes, for in the roughage, containing more fiber, a larger part of the energy in the digested nutrients is used up in the non-productive work of mastication, digestion, and assimilation. (**78-80**) In the ordinary rations for each class of animals, concentrates and roughages are, however, usually fed in about the same proportions. This tends to lessen any error due to inaccuracy in computing rations according to the Wolff-Lehmann method. Furthermore, the prescription of a definite allowance of dry matter is a check upon the net-energy value of the ration. If a ration contains sufficient digestible nutrients to meet the Wolff-Lehmann standards, but carries an excess of dry matter, obviously too much roughage or concentrates too high in fiber have been used and the net-energy value will consequently be too low. On the other hand, if the content of digestible nutrients satisfies the standard, while the ration does not contain the dry matter called for, it indicates that feeds more concentrated in character than necessary have been used, in which case some roughage or feeds higher in fiber may be substituted till the dry-matter content is brought up to the standard. With this simple check any large error in formulating the ration may be avoided.

188. Necessity for modifying the Wolff-Lehmann standards.—It has already been shown in this chapter that in several instances the original Wolff-Lehmann standards do not set forth the actual requirements of farm animals as revealed by the many experiments which have been carried on since these standards were drawn up. We know, for example, that the allowance of digestible crude protein prescribed is higher than is needed by fattening animals, dairy cows, and work horses. Yet these standards are today more commonly employed in this country, except perhaps with the dairy cow, than any other system for formulating rations. Indeed, the authors have recently found feeders, annually fattening hundreds and even thousands of animals, who were balancing rations according to the original Wolff-Lehmann standards by the addition of unnecessary amounts of high-priced protein-rich concentrates.

189. Modified Wolff-Lehmann standards.—With these facts in mind the authors have attempted to combine in one standard what appear in their judgment to be the best guides we have at present in the formulation of rations for various classes of animals. To facilitate the computations, the standards, which are given in detail in Appendix Table V, are expressed simply in terms of total dry matter, digestible crude protein, and total digestible nutrients. Realizing that feeding standards are but approximations, in most cases minimum and maximum figures are given for dry matter, digestible crude protein, and total digestible nutrients. Since progressive feeders thruout the country now appreciate the significance of the nutritive ratio of a ration, the approximate upper and lower advisable limits of nutritive ratios for the different classes have been stated. To correspond with these standards a column has been added to Appendix Table III, showing the total digestible nutrients furnished in 100 lbs. of each feed. Likewise, so that one may see at a glance which feeds are high and which are low in protein, compared with carbohydrates and fat, the nutritive ratio for each feed has been computed and is given in the table. With these aids it is hoped that the standards presented may be of real assistance to students and feeders who desire to compute rations substantially in accordance with the Wolff-Lehmann method, while recognizing the results of the later investigations in animal feeding.

The recommendations gathered together in these standards are from many sources. The standards for the dairy cow are those formulated by Haecker and Savage. The data for growing, fattening steers have been kindly furnished by Haecker,[25] and are based upon his extensive investigations of the nutrient requirements of steers of various ages. **(123)**

[25] Information to the authors.

The figures for fattening 2-yr.-old steers and for growing, fattening pigs are based chiefly upon studies made at the Wisconsin Station by the junior author[26] of the feeding experiments carried on at American stations. Those for fattening lambs are computed from the Bull-Emmett standards, based on their study of American feeding trials, and that for work horses from the investigations of Zuntz and from American feeding trials. In revising the requirements for the other classes of animals there have been utilized the Kellner and Armsby standards, which have already been discussed, and the extensive standards of Pott[27] of Germany, which are formulated in substantially the same terms as the Wolff-Lehmann standards.

190. Ration for fattening 2-yr.-old steers.—To illustrate the manner of computing rations in accordance with the Modified Wolff-Lehmann standards, let us formulate a ration for fattening 2-yr.-old feeder steers. The steers, averaging 900 lbs. when placed in the feed lot, are to be fed a heavy fattening ration for 150 days so that they will gain 2.4 lbs. per head daily, or more. The Modified Wolff-Lehmann standards for 2-yr.-old steers on full feed are as follows:

Modified Wolff-Lehmann standards for 2-yr.-old steers on full feed (From Appendix Table V)

	Per 1,000 lbs. live weigbt			Nutritive ratio
	Dry matter	Minimum of dig. crude protein	Total dig. nutrients	
	Lbs.	Lbs.	Lbs.	
First 50 to 60 days	22–25	2.0–2.3	18.0–20.0	1:7.0–1:7.8
Second 50 to 60 days	21–24	1.9–2.3	17.0–19.5	1:7.0–1:7.8
Third 50 to 60 days	18–22	1.8–2.1	16.0–18.5	1:7.0–1:7.8

It will be noted that the allowance of dry matter is the largest for the first 50 to 60 days of fattening. During this period the steers are being brought to a full feed of grain and are hence consuming a larger proportion of roughage to concentrates than in the later periods. The amount of total digestible nutrients required per 1,000 lbs. live weight also decreases as the steers fatten, but not so much as does the dry matter. The minimum amount of digestible crude protein advised for the first period is 2.0 to 2.3 lbs. per 1,000 lbs. live weight. The larger amount will probably tend to slightly more rapid fattening than the lower figure, but as is pointed out later, may be less economical than the lesser amount. (**196**)

On comparing these standards, which are based on the results of American feeding trials, with the original Wolff-Lehmann standards, it

[26] The compilation and computation of data in the study of the pig feeding experiments was chiefly done by Messrs. M. L. Geraldson and J. G. Poynton, students in the Wis. College of Agriculture. Mr. G. Bohstedt, a graduate student in the same College, has assisted in the compilation of still other data upon which these standards are based.

[27] Handb. Ernähr. u. Futter., I, 1907, pp. 374–376.

is seen that the minimum allowance of digestible crude protein advised is considerably lower than in the original standards. The dry matter is also materially lower, for fattening steers fed roughage of good quality, as is commonly done in this country, will not consume as much dry matter as set forth in the original Wolff-Lehmann standards.

In formulating rations for these steers, the most accurate way is to compute the rations on the basis of the average live weight of the steers during each period of fattening. If the steers weigh 900 lbs. when placed on feed and gain 2.4 lbs. per head daily, their average weight for the first 50 days will be 1,020 lbs.; for the second 50 days, 1,140 lbs.; and for the last 50 days, 1,260 lbs. Computing the standard requirements for each period on this basis we have:

Requirements for given steers at different periods of fattening

	Av. wt. during period	Dry matter	Dig. crude protein	Total dig. nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Lbs.	
First 50 days.....	1,020	22.4–25.5	2.04–2.35	18.4–20.4	1:7.0–1:7.8
Second 50 days......	1,140	23.9–27.4	2.17–2.62	19.4–22.2	1:7.0–1:7.8
Third 50 days.......	1,260	22.7–27.7	2.27–2.65	20.2–23.3	1:7.0–1:7.8

Owing to the greater weight of the cattle in the last periods, tho they require less dry matter and total digestible nutrients per 1,000 lbs. live weight, the requirements per steer are slightly greater. Let us now formulate rations to meet these requirements. The steers are to be fed all the well-matured corn silage and good clover hay they will clean up, morning and night, and shelled corn is to be fed as the chief concentrate, with choice cottonseed meal if needed to balance the ration. As shown later (**776**), 2-yr.-old steers full fed on corn will eat 25 to 30 lbs. of corn silage during the first period of fattening and gradually less as fattening progresses. Owing to the palatability of the silage they will usually eat only 3 to 6 lbs. of clover hay. For a trial ration during the first period we will therefore take 28 lbs. of corn silage, 4 lbs. of clover hay, and enough shelled corn to bring the amount of total digestible nutrients up to the standard. As shown in the following table, this will require 14 lbs. of corn:

Trial ration for fattening 2-yr.-old steers, first period

Feeding stuff	Dry matter	Dig. crude protein	Total dig. nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	
Corn silage, 28.0 lbs...............	7.36	0.308	4.96	
Clover hay, 4.0 lbs...............	3.48	0.304	2.04	
Shelled corn, 14.0 lbs...............	12.53	1.050	12.00	
Total.........................	23.37	1.662	19.00	1:10.4

This ration furnishes sufficient total digestible nutrients and agrees with the standard in dry matter, but falls far short in protein. Let us, therefore, replace some of the corn with cottonseed meal. As we wish these steers to make maximum gains we will supply somewhat more protein than called for by the lowest figure in the standard. Substituting 2.0 lbs. of choice cottonseed meal for the same weight of corn, we will have the ration shown in the first division of the following table. This agrees well with the standard and should produce rapid gains when fed to thrifty feeders. In the same manner we will formulate rations for the middle and the last periods of fattening, bearing in mind that steers on full feed will eat less roughage and more concentrates as they fatten. Since we wish these steers to reach a high finish we will increase the protein supply during the last period to the higher figure set forth in the standard, 2.65 lbs. per head daily. Arranging the data as before, we will have the rations shown in the table:

Rations for fattening 2-yr.-old steers, for first, second, and third periods

Feeding stuff	Dry matter	Dig. crude protein	Total dig. nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	
First 50 days				
Corn silage, 28.0 lbs.	7.36	0.308	4.96	
Clover hay, 4.0 lbs.	3.48	0.304	2.04	
Shelled corn, 12.0 lbs.	10.74	0.900	10.28	
Cottonseed meal, 2.0 lbs.	1.85	0.740	1.56	
Total	23.43	2.252	18.84	1:7.4
Second 50 days				
Corn silage, 24.0 lbs.	6.31	0.264	4.25	
Clover hay, 3.0 lbs.	2.61	0.228	1.53	
Shelled corn, 15.0 lbs.	13.42	1.125	12.86	
Cottonseed meal, 2.5 lbs.	2.31	0.925	1.96	
Total	24.65	2.542	20.60	1:7.1
Third 50 days				
Corn silage, 21.0 lbs.	5.52	0.231	3.72	
Clover hay, 3.0 lbs.	2.61	0.228	1.53	
Shelled corn, 16.0 lbs.	14.32	1.200	13.71	
Cottonseed meal, 2.75 lbs.	2.54	1.018	2.15	
Total	24.99	2.677	21.11	1:6.9

These rations meet the standards in all particulars and should give good results in practice. (**777**) As is explained later (**196**), when protein-rich feeds are high in price compared with those carbonaceous in character, it may be more economical to supply only as much protein as called for in the lower figures in the standard. If the steers were to be fattened more slowly, the rations could be computed in accordance with the standards for "growing, fattening steers," based on Haecker's extensive studies. These would require less concentrates and in many instances result in much cheaper gains. (**716, 768, 780**)

CHAPTER VIII

ECONOMY IN FEEDING LIVE STOCK

I. Selecting Economical Rations

To secure the largest returns from his farm animals the stockman must, first of all, thoroly understand the fundamental nutrient requirements of the various classes of live stock which have been discussed in the preceding chapters. He must next study the possibilities of his farm for the production of crops, paying attention to both the probable yields and the value of the various crops for feeding to stock or for selling on the market. It is also necessary to consider the feeding value of the many feeds on the market and compare the prices at which they can be secured. With this knowledge he is in a position to plan his rotations so that from the crops raised, supplemented when it is economical by purchased feeds, well-balanced rations for his stock may be provided at minimum expense. As a rule it will be found wise to raise all needed roughage on the farm. Owing to the increasing demand for the cereal grains for human consumption, it is often economical to sell more or less of the farm-grown grains and replace them with purchased concentrates which economically supplement the feeds raised on the farm.

191. Market prices not guides to value.—On studying the market prices of different feeds it will be evident that the market price is often no index to the value of a feed to the individual stockman. A few examples will illustrate this fact. In the northeastern states timothy hay is generally higher in price than clover hay, tho it is much inferior to clover for all animals except the horse. In the South cottonseed hulls usually cost more than the sum for which an equivalent amount of corn silage, a much more palatable feed, can be produced on the farm. Owing to their popularity, some feeds, such as linseed meal and wheat bran, are often high in price compared with other concentrates which are entirely satisfactory substitutes. At the other extreme, low grade concentrates, such as trashy corn and oat feed, cottonseed feed, and inferior mixed feeds often sell for as much or but slightly less than high grade concentrates of far greater feeding value.

192. How to select feeds for economical rations.—Many attempts have been made to assign a definite money value to 1 lb. of digestible crude protein, digestible carbohydrates, and digestible fat, and then compute the value of different feeds on the basis of the amount of these nutrients they contain, the same as is commonly done in arriving at the money value of fertilizers. (432) While such a system of valuation may be of some limited value for a short period of time and when applied to a small district where the systems of farming do not vary widely, no such set of values has general application to the United States. As has been emphasized before (178), the value of any given feed to the stockman depends on the nature and composition of the other feeds he has at hand. If his chief roughage is alfalfa hay, protein-rich concentrates are often worth less to him than those rich in carbohydrates. On the other hand, if the cheapest roughage he can provide is corn or sorghum silage, low in protein, then concentrates rich in protein will be of higher value to him than those carbonaceous in character.

In planning economical rations for any class of animals the stockman should first choose from suitable feeds a combination, containing the proper proportion of concentrates and roughages, which will supply the necessary total amount of nutrients at the minimum expense. If this ration is too low in protein, protein-rich feeds should be substituted for those lower in protein, until the protein supply is brought to the desired amount. On the other hand, if the ration which supplies the necessary total amount of nutrients is too rich in protein, then carbonaceous feeds should be substituted until the nutritive ratio is widened as much as is desired.

In determining which feeds furnish total nutrients at the lowest price, the comparisons may be made on the basis of the cost per therm of net energy, per feed-unit, or per pound of total digestible nutrients. For the reasons pointed out in preceding articles (177-8), the authors believe that the most convenient system for American farmers is on the basis of the cost per pound of total digestible nutrients. In comparing roughages with concentrates this system gives roughages somewhat too high a relative value, for 1 lb. of total digestible nutrients in a roughage is lower in net energy than 1 lb. of digestible nutrients in concentrates. However, in most cases, the desire will be, not to compare roughages with concentrates, but, instead, to determine which one of several concentrates is the cheapest source of total nutrients, or which of the different available roughages is the most economical feed. To determine which feeds are the cheapest supplements to balance a ration low in protein, it will be found convenient to compute the cost of the different feeds per pound of digestible crude protein.

In comparing the relative cheapness of different feeds, it is reasonable to value marketable farm-grown grain or roughage at the market price less the cost of hauling to market. Feeds which are not usually marketable may be assigned a value based on the cost of production. To the price of any purchased feeds should be added any cost of hauling to the farm. Often, however, purchased concentrates may be brought back to the farm on a return trip from market with little or no additional expense.

193. A comparison of corn-belt feeds for milk production.—To illustrate the manner in which the prices of the available feeds should be studied in computing rations, let us assume that a dairyman in the corn belt has available the following: Ground dent corn at $20, ground oats at

$25, ground barley at $26, timothy hay at $16, red clover hay at $12, and corn silage from well-matured corn at $3.50 per ton. He can purchase hominy feed at $26, high-grade gluten feed at $30, wheat bran at $25, corn and oat feed at $25, choice cottonseed meal at $34, old-process linseed meal at $34, and alfalfa meal at $22 per ton. For convenience we will arrange in tabular form the data from Appendix Table III for these different feeds, and compute the cost per pound of digestible crude protein and the cost of 1 lb. of total digestible nutrients in each.

Comparison of the economy of various feeds at the stated prices

Feeding stuff	Dry matter in 100 lbs.	Dig. crude protein in 100 lbs.	Total dig. nutrients in 100 lbs.	Nutritive ratio	Price per ton	Cost per lb. of dig. crude protein	Cost of 1 lb. of total dig. nutrients
	Lbs.	Lbs.	Lbs.	1:	Dollars	Cents	Cents
Concentrates							
Dent corn	89.5	7.5	85.7	10.4	20.00	13.33	1.17
Hominy feed	89.9	7.0	84.6	11.1	26.00	18.57	1.54
Gluten feed, high grade	91.3	21.6	80.7	2.7	30.00	6.94	1.86
Wheat bran, all analyses	89.9	12.5	60.9	3.9	25.00	10.00	2.05
Oats	90.8	9.7	70.4	6.3	25.00	12.89	1.78
Corn and oat feed	88.6	7.3	75.6	9.4	25.00	17.12	1.65
Barley, ground	90.7	9.0	79.4	7.8	26.00	14.44	1.64
Cottonseed meal, choice	92.5	37.0	78.2	1.1	34.00	4.59	2.17
Linseed meal, old-process	90.9	30.2	77.9	1.6	34.00	5.63	2.18
Distillers' grains, dried, from corn	93.4	22.4	88.9	3.0	31.00	6.92	1.74
Roughages							
Timothy hay, all analyses	88.4	3.0	48.5	15.2	16.00	26.67	1.65
Alfalfa meal	91.2	10.2	50.7	4.0	22.00	10.78	2.17
Red clover hay, all analyses	87.1	7.6	50.9	5.7	12.00	7.89	1.18
Corn silage, recent analyses	26.3	1.1	17.7	15.1	3.50	15.91	0.99

This table does not assume to represent average conditions in any district of the country, but illustrates the manner in which any stockman may compare the relative economy of the different available feeds at local prices. The last column shows clearly that, for the feeds given and with prices as stated, corn is by far the cheapest source of total digestible nutrients among the concentrates. Of the roughages, corn silage supplies total digestible nutrients most cheaply, followed by clover hay. For balancing a ration deficient in protein, cottonseed meal will furnish digestible crude protein at 4.59 cts. per pound, linseed meal at 5.63 cts., dried distillers' grains at 6.92 cts., gluten feed at 6.94 cts., red clover hay at 7.89 cts., and wheat bran at 10.00 cts. In supplying protein these feeds will of course also furnish carbohydrates and fat as well, which are included in the total digestible nutrients.

194. A corn-belt ration for milk production.—From the feeds listed let us now formulate the most economical ration which will be satisfactory for a 1200-lb. cow yielding daily 30 lbs. of 3.5 per ct. milk. For this cow there will be required, according to the Modified Wolff-Lehmann standard (**Appendix Table V**) a minimum daily allowance of 2.31 to

2.67 lbs. digestible crude protein and 18.99 lbs. total digestible nutrients. The ration should contain from 25 to 30 lbs. of dry matter, and should have a nutritive ratio no wider than 1 : 6.1 to 1 : 7.2.

Altho corn silage is the cheapest roughage available, some dry roughage should be fed with it to dairy cows. (**629, 664**) Of the dry roughages, clover hay is the cheapest. Let us then follow the general rule of feeding 1 lb. of dry roughage and 3 lbs. of silage per 100 lbs. live weight. (**167**) To this allowance of roughage, we will add enough corn to bring the total digestible nutrients up to the amount advised in the standard, for corn is the concentrate which furnishes total digestible nutrients most cheaply. Tabulating the results we will have:

First trial ration for 1200-lb. cow yielding 30 lbs. of 3.5 per ct. milk

Feeding stuff	Dry matter	Dig. crude protein	Total dig. nutrients	Cost	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Cents	
Clover hay, 12.0 lbs.	10.45	0.912	6.108	7.20	
Corn silage, 36.0 lbs.	9.47	0.396	6.372	6.30	
Corn, dent, 8.0 lbs.	7.16	0.600	6.856	8.00	
Total	27.08	1.908	19.336	21.50	1:9.1

This ration, which costs 21.5 cts., meets the standard in total digestible nutrients and dry matter but is decidedly deficient in protein. We could narrow the nutritive ratio by feeding less silage and more clover hay, but corn silage is the cheapest feed available. Therefore we should substitute protein-rich concentrates for a part of the dent corn.

If 1.5 lbs. of cottonseed meal was substituted for the same weight of corn the ration would furnish about 2.3 lbs. of digestible crude protein, the minimum amount recommended in the standard. Ground corn and cottonseed meal are, however, both heavy feeds, weighing about 1.5 lbs. per quart. (**Appendix Table VII**) It is hence desirable to add some bulky concentrate which is also high in protein. Dried distillers' grains are about as bulky as wheat bran and furnish protein much more cheaply. Alfalfa meal is not so economical as distillers' grains, and gluten feed is a somewhat heavier feed. Let us then substitute 0.5 lb. of cottonseed meal and 2.0 lbs. of dried distillers' grains for 2.5 lbs. of corn, and again tabulate the results:

Second trial ration for 1200-lb. cow yielding 30 lbs. of 3.5 per ct. milk

Feeding stuff	Dry matter	Dig. crude protein	Total dig. nutrients	Cost	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Cents	
Clover hay, 12.0 lbs.	10.45	0.912	6.108	7.20	
Corn silage, 36.0 lbs.	9.47	0.396	6.372	6.30	
Corn, dent, 5.5 lbs.	4.92	0.412	4.714	5.50	
Cottonseed meal, 0.5 lb.	0.46	0.185	0.391	0.85	
Distillers' grains, dried, 2.0 lbs.	1.87	0.448	1.778	3.10	
Total	27.17	2.353	19.363	22.95	1:7.2

This ration, which costs 22.95 cts., supplies the minimum amount of protein recommended by the standard, and is slightly above it in total digestible nutrients. Tho costing 1.45 cts. more than the first ration, it will be more economical for it should produce much better results. The concentrate mixture weighs about 1.2 lbs. per quart, being somewhat heavier than advised by some dairymen. Such mixtures as this have, however, been satisfactory in practice.

It is explained elsewhere that the lower amounts of digestible crude protein advised for the dairy cow in the Modified Wolff-Lehmann standards are the amounts recommended by Haecker, while the higher figures are those set forth by Savage. (**182, 184, 186; Appendix Table V**) As has been stated before (**186**), for cows of pronounced dairy temperament it may be advisable to feed as much protein as called for by the higher figures, providing this does not greatly increase the cost of the ration. Let us then see how cheaply a ration can be provided which will supply 2.67 lbs. of digestible crude protein, the higher figure advised by the standard. The protein can be added most cheaply by substituting more cottonseed meal for corn, but instead of merely using more cottonsed meal, let us feed 1 lb. of wheat bran, which will lighten the concentrate mixture and which is much relished by the cow. At the prices given bran is an expensive source of protein, since it is not high in that nutrient. The price per pound of total digestible nutrients is, however, slightly lower than that of cottonseed meal. Arranging the results as before, we will have:

Third trial ration for 1200-lb. cow producing 30 lbs. of 3.5 per ct. milk

Feeding stuff	Dry matter	Dig. crude protein	Total dig. nutrients	Cost	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Cents	
Clover hay, 12.0 lbs.	10.45	0.912	6.108	7.20	
Corn silage, 36.0 lbs.	9.47	0.396	6.372	6.30	
Corn, dent, 3.5 lbs.	3.13	0.262	3.000	3.50	
Cottonseed meal, 1.5 lbs.	1.39	0.555	1.173	2.55	
Distillers' grains, dried, 2.0 lbs.	1.87	0.448	1.778	3.10	
Wheat bran, 1.0 lb.	0.90	0.125	0.609	1.25	
Total	27.21	2.698	19.040	23.90	1:6.1

This ration, which has a nutritive ratio of 1:6.1, costs about 1 cent more than the preceding ration. The concentrate mixture will be preferred by many dairymen, for it is more bulky, weighing 1.1 lbs. per quart. Whether this ration will produce enough more milk to pay for the increased cost will depend on how pronounced is the dairy temperament of the particular cow getting the ration.

195. A cotton-belt ration for milk production.—Let us next use the method which has just been illustrated in determining the most economical ration for the same cow if owned by a southern dairyman who has the following feeds available: Ground corn at $30, oats at $35, corn silage at $3.50, cowpea hay at $15, and Johnson grass hay at $15 per ton. Cottonseed meal may be secured at $25, dried distillers' grains at $29, dried beet pulp at $29, wheat bran at $32, and cottonseed hulls at $7.50 per ton. Arranging the data for these feeds as before, we will have the following:

Comparison of the economy of various feeds at the stated prices

Feeding stuff	Dry matter in 100 lbs.	Dig. crude protein in 100 lbs.	Total dig. nutri-ents in 100 lbs.	Nutri-tive ratio	Price per ton	Cost per lb. of dig. crude protein	Cost of 1 lb. of total dig. nutri-ents
	Lbs.	Lbs.	Lbs.	1:	Dollars	Cents	Cents
Concentrates							
Dent corn	89.5	7.5	85.7	10.4	30.00	20.00	1.75
Wheat bran, all analyses	89.9	12.5	60.9	3.9	32.00	12.80	2.63
Oats	90.8	9.7	70.4	6.3	35.00	18.04	2.49
Cottonseed meal, choice	92.5	37.0	78.2	1.1	25.00	3.38	1.60
Dried beet pulp	91.8	4.6	71.6	14.6	29.00	31.52	2.03
Distillers' grains, dried, from corn	93.4	22.4	88.9	3.0	29.50	6.59	1.66
Roughages							
Cottonseed hulls	90.3	0.3	37.0	122.3	7.50	125.00	1.01
Johnson grass hay	89.9	2.9	50.1	16.3	15.00	25.86	1.50
Cowpea hay, all analyses	90.3	13.1	49.0	2.7	15.00	5.73	1.53
Corn silage, recent analyses	26.3	1.1	17.7	15.1	3.50	15.91	0.99

With feeds at these prices cottonseed meal is not only the cheapest source of protein, but also furnishes total digestible nutrients at the lowest price among the concentrates. However, it is not safe to feed too large an allowance of this concentrate. (**249-50, 596-7**) In economy with which they furnish total digestible nutrients, dried distillers' grains and dent corn rank close to cottonseed meal. Among the roughages, corn silage is still the cheapest source of total digestible nutrients, followed by cottonseed hulls. Cowpea hay and Johnson grass hay furnish total digestible nutrients at about the same price.

Since it is economy to feed a large allowance of cottonseed meal, which is exceedingly rich in protein, the roughage allowance should be relatively low in protein. We might feed only corn silage and cottonseed hulls as roughage, but for the improvement of southern farms it is highly important that legumes be included in the crop rotation. Tho cowpea hay is more expensive than cottonseed hulls, when the benefit to the soil from growing the crop is considered the wise dairyman will decide to raise cowpeas or some other legume and feed the resulting hay. Let us then first compute a ration with a heavy allowance of silage, 42 lbs., with 8 lbs. of cowpea hay and 3.5 lbs. of cottonseed hulls, and to this add sufficient choice cottonseed meal to bring the total digestible nutrients up to the standard. On computing we will find that about 8 lbs. is required, as is shown in the table:

First trial ration for 1200-lb. cow yielding 30 lbs. of 3.5 per ct. milk

Feeding stuff	Dry matter	Dig. crude protein	Total dig. nutrients	Cost	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Cents	
Corn silage, 42.0 lbs.	11.05	0.462	7.434	7.35	
Cowpea hay, 8.0 lbs.	7.22	1.048	3.920	6.00	
Cottonseed hulls, 3.5 lbs.	3.16	0.010	1.295	1.31	
Cottonseed meal, 8.0 lbs.	7.40	2.960	6.256	10.00	
Total	28.83	4.480	18.905	24.66	1:3.2

This ration contains more cottonseed meal than is safe and has too narrow a nutritive ratio. To improve it we should substitute concentrates which are lower in protein and also bulkier. Of the concentrates listed dried beet pulp best meets both these requirements. It is much more economical than oats or bran, and is bulkier than corn which supplies total digestible nutrients somewhat more cheaply. Let us therefore substitute 2 lbs. of dried beet pulp for the same weight of cottonseed meal and likewise replace 1.5 lbs. of cottonseed meal with the same weight of dried distillers' grains, which are bulky, lower in protein than cottonseed meal, and nearly as cheap a source of total digestible nutrients. We will then have:

Second trial ration for 1200-lb. cow yielding 30 lbs. of 3.5 per ct. milk

Feeding stuff	Dry matter	Dig. crude protein	Total dig. nutrients	Cost	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Cents	
Corn silage, 42.0 lbs.	11.05	0.462	7.434	7.35	
Cowpea hay, 8.0 lbs.	7.22	1.048	3.920	6.00	
Cottonseed hulls, 3.5 lbs.	3.16	0.010	1.295	1.31	
Cottonseed meal, 4.5 lbs.	4.16	1.665	3.519	5.62	
Dried beet pulp, 2.0 lbs.	1.84	0.092	1.432	2.90	
Dried distillers' grains, 1.5 lbs.	1.40	0.336	1.334	2.21	
Total	28.83	3.613	18.934	25.39	1:4.2

This ration costs only 0.73 cts. more than the first, and does not contain more cottonseed meal than is safe when fed in mixture with bulky concentrates along with succulent feed like silage. It is evident that with feeds at the prices given in this illustration the question is not how little protein need be supplied, but how much may be safely fed.

The 2 examples which have been given in the preceding pages—the most economical ration for the particular corn-belt dairyman, and the best ration for a given cotton-belt dairyman—show how widely the character of the ration should be changed to make it the most economical under conditions in different parts of the country or with varying prices for the various feeding stuffs. The farmer who wishes to secure the largest returns from his stock should use a similar method to determine the relative economy of the available feeds for all his farm animals.

II. Adapting Systems of Feeding to Local Conditions

196. Amount of protein to supply.—The illustrations given in the preceding articles show clearly that rations should be adapted to the local conditions. Feeding standards set forth approximately the amount of protein and total nutrients, which it is believed should be furnished for the maximum production of flesh, milk, work, etc., and for maintaining the highest well-being of the animal. It will be noted that in the Modified Wolff-Lehmann standards a range is indicated in the amount of digestible crude protein advised for most classes of animals. For example, for 2-yr.-old steers on full feed from 2.0 to 2.3 lbs. of digestible crude protein per 1,000 lbs. live weight are recommended for the first 50–60 days of fattening. When protein-rich feeds cost but little or no more than carbonaceous feeds, it is well to feed at least as much protein as indicated by the higher figures. On the other hand, when corn or the other grains are relatively cheap it may be better economy to feed no more protein than called for by the lower figures. Rarely is it advisable to feed a materially smaller allowance of protein than the lower figures, for the production will be thereby lowered.

As is shown later (**732, 844-5**), corn and clover hay alone make a fairly well-balanced ration for fattening cattle and sheep. However, the gains are usually slightly increased and a higher finish secured when a small allowance of some suitable nitrogenous concentrate is added to the ration. Whether such addition will be profitable or not depends on the prices of the feeds and on whether the market will pay a better price for the more highly finished animal. (**733, 858**)

When protein-rich feeds supply nutrients more cheaply than those carbonaceous in character, as in the cotton belt and the alfalfa districts of the West, it will be economy to feed much more than the minimum amounts of protein set forth in the standards. (**612, 768**) However, protein should not be supplied in such excess as to injure the health of the animals.

197. Proportion of concentrates to roughages.—To meet the standards for fattening cattle and sheep and for milch cows, fairly liberal amounts of concentrates are required. When concentrates furnish total digestible nutrients nearly as cheaply as do roughages it is advisable to feed as large a proportion of concentrates as is called for by the standards. With feeds at the prices given in Article **193** dent corn furnishes nutrients at no greater cost than red clover hay. Under such conditions it may be most profitable to feed fattening steers and sheep as much corn as they will clean up. (**716, 902, 906-7**) On the other hand, in many of the alfalfa districts of the West, grain is usually high in price compared with alfalfa hay. Here it may be more profitable to restrict the grain allowance, even tho gains are slower. (**768**)

With dairy cows much depends on the productive capacity of the animal. Except when concentrates are unusually high in price, the cow of good dairy temperament will pay for at least a fair allowance of concentrates. On the contrary, for a low or limited productive capacity the most economical ration may be silage and legume hay with no concentrates. (**658-9**)

198. Roughing growing animals thru the winter.—The recommendations of the standards for growing cattle and sheep are based upon continuous thrifty growth, and hence call for a limited allowance of concentrates in addition to roughage. The breeder of pure-bred animals who wishes to develop the best there is in his young stock will feed the concentrates needed to keep them growing rapidly. On the other hand, the western beef producer may find it most profitable to carry young stock thru the winter on roughage alone or with but a small allowance of concentrates. Thus fed, they will gain in frame, and tho losing in flesh, will be thrifty enough in the spring to make good gains on the cheap pasturage. (**138-9, 797-9**)

199. Finish animals to meet demands of the market.—The wise stockman will keep in close touch with the demands of the market and adjust his feeding operations accordingly. If the market pays a sufficient premium for thoroly fattened animals he will finish his stock well before marketing them. On the other hand, on local markets which pay no more for a prime carcass than for one carrying less fat, it will pay not to prolong the fattening process or to feed as heavy an allowance of concentrates as is necessary to make the carcass "ripe," or thoroly fat. (**121-2, 768, 800**)

200. Adapt type of farming to local conditions.—It is outside the field of this volume to discuss in detail the many factors which the stockman should take into consideration in deciding the type of live-stock husbandry in which to engage and the systems and methods to follow. The foregoing paragraphs serve to illustrate how the farm operations and practices should be suited to local conditions, taking into consideration price of land and labor, nearness to market, and available crops. For example, the beef producer on high-priced land in the eastern part of the corn belt will generally crowd his calves to rapid growth on a heavy allowance of grain and fatten them as baby beef. Or he will raise no cattle, but fatten feeder steers from the western ranges on a liberal allowance of corn. On the other hand, in the West where pasture is cheap compared with grain the stockman will usually follow a less intensive system, roughing his growing stock thru the winter and marketing them from grass as 2- or 3-yr.-olds, having been fed little grain at any time.

The market milk for our cities must come from the surrounding districts which are within easy shipping distance. Dairymen maintaining herds on high-priced land to meet this demand properly tend to use a minimum acreage as pasture, but instead rely largely on corn silage or soilage during the summer months. They often buy much of their concentrates, for grain can be produced on land farther from market and shipped in at less expense than it may be possible to grow it on their farms. Such a system is not, however, economical for the dairyman remote from the large markets, whose milk is used in the manufacture of butter or cheese. Since with him land is relatively less expensive than labor, he must adopt a less intensive system of dairying, where the herd is maintained largely on pasture in the summer.

The reader will come to realize as he goes on in this book that, while there are no hard and fast rules for successfully managing live stock, a clear understanding of the principles of the nutrition of animals is essential to the highest success. This must be supplemented by good judgment and by a thoro knowledge of the farm animals themselves, which can only be gained by actual experience. He will further find that expensive buildings for housing stock and complex devices for feeding and caring for them are not necessary; that there are no "best" feeds for all conditions; that elaborate and laborious preparation of feed is often wasted; that patent stock foods guaranteed to work miracles enrich, not the farmer, but the manufacturer.

On the other hand he will come to appreciate that a proper balancing of the rations for his stock not only benefits the animals, but also increases his profits; that comfort for farm stock can be secured in inexpensive, easy ways, and that the operations of preparing and administering feed are really simple and direct, when once understood. He will further come to the deep and fundamental realization that animal husbandry under normal conditions is most successful when combined with general farming and the raising of farm crops, that it rests upon pasture lots which are fertilized so as to produce abundant forage and upon tilled fields which are so managed that the fertility is maintained and bumper crops are grown, a large part of which is marketed thru the animals of the farm.

Having discussed in the preceding chapters the fundamental principles governing the rational feeding and care of the various classes of farm animals, let us now consider in detail the value of the many different feeding stuffs for live stock.

Part II

FEEDING STUFFS

CHAPTER IX

LEADING CEREALS AND THEIR BY-PRODUCTS

I. Indian Corn and its By-products

The prime importance of Indian corn, or maize, *Zea mays,* as a grain crop in the United States is evident from the fact that in 1914, about 103,435,000 acres were grown, producing two and a half billion bushels of grain, worth $1,720,000,000. In acreage, in total production, and in value of grain, the corn crop of the United States exceeds that of wheat, oats, barley, rye, kafir, milo, emmer, buckwheat, and rice, combined. Indian corn can be successfully grown in every state of the Union, tho it flourishes best in the great middle region of our country lying between the Appalachians and the Rocky Mountain Plateau. In the South the tropical corn stems, 4 or 5 months from planting, carry great ears burdened with grain so high that a man can only touch them by reaching high above his head. At the other extreme, the Mandan Indian in the country of the Red River of the North developed a race of corn which reached only to the shoulders of the squaw, with tiny ears borne scarcely a foot from the ground on pigmy stalks. Corn is a heat-loving plant, and will not thrive in regions having cool nights during the growing season.

Like the other leading cereals which grow *en masse,* the corn plant must grow with others of its kind, but it requires more space, air, and sunlight. Because it requires thoro tillage and makes most of its growth during late summer and early fall, Indian corn stands in a class by itself among the cereals. (**23**) This requirement of thoro tillage brings many advantages to the soil not forced upon us in growing the other cereals. The corn grain is pre-eminently a carbohydrate bearer, every 100 lbs. containing nearly 70 lbs. of starch, which is its chief carbohydrate. Add to this 5 lbs. of oil, and we can understand why Indian corn among the cereal grains may be likened to anthracite coal among the fuels.

Corn is the great energizing, heat-giving, fat-furnishing food for the animals of the farm. No other cereal yields, on a given space and with a given expenditure of labor, so much animal food in both grain and forage. On millions of farms successful animal husbandry rests upon this imperial grain and forage plant. (**475, 575, 732-7, 844-7, 939-42**) A possible explanation of the great fondness of farm animals for corn lies in the considerable amount of oil it carries. Again, on mastication the kernels break into nutty particles which are more palatable, for example, than meal from the almost oil-free wheat grain, which on crushing and mingling with the saliva turns to a sticky dough in the mouth. (For a discussion of corn as a forage, see Arts. **290** to **307**.)

201. Corn lacks protein and mineral matter.—Being so rich in carbohydrates, corn is naturally low in crude protein. The crude protein of this grain is also somewhat unbalanced, for about 58 per ct. of it consists of the single protein, zein, which lacks some of the amino-acids necessary for animal growth. (**118**) Corn is also unusually low in mineral matter, especially calcium, so necessary for growing animals. Numerous experiments show that even with fattening animals, which require relatively little protein and mineral matter, it is profitable to supplement these deficiencies of the corn grain by other feeds high in the nutrients which corn lacks. (**732, 845, 939**) Fortunately, the legume hays are rich in protein and calcium, and therefore admirably supplement corn. By the use of these roughages, less protein-rich concentrates are needed to balance a heavy allowance of corn. Indeed, for some animals legume hay and corn alone form a satisfactory, well-balanced ration. (**733, 844**)

202. Races of corn.—Three races of corn—dent, flint, and sweet—are of interest to the stockman. In dent corn the starch is partly hornlike and partly floury, rendering the kernel easy of mastication. In flint corn the starch is mostly hornlike and flinty, making the kernel more difficult for the animal to crush. Both chemical analysis and experience oppose the assertion, often heard, that yellow corn is more nutritious than white, or the opposite. In fact, the coloring matter of yellow corn is so minute in quantity as to be unweighable. While a certain strain or variety of one may be superior to any particular strain or variety of the other in a given locality, there is no uniform difference between white and yellow corn in productiveness or feeding properties.

In sweet corn the starch is hornlike and tough. Before hardening, the milky kernels of this race carry much glucose, which is changed to starch as they mature into the shrunken grain. The sweetness of the immature grains of sweet corn, due to the glucose they then carry, adds to the palatability but not necessarily to their nutritive value, since glucose and starch have the same feeding value. (**48**) Sweet corn has somewhat more crude protein and fat and less carbohydrates than the other races.

Earliness of maturity tends to dwarf the corn plant. Hence, the higher the latitude or the altitude at which a variety was originated the larger will be the proportion of ears to stalk and leaves, tho the total yield of ears will usually be decreased.

203. Corn cobs.—Well-dried dent ear corn of good breeding carries about 56 lbs. of shelled corn to 14 lbs. of cob. The proportion of cob to grain varies according to race, variety, and dryness, ranging from below 20 to about 40 per ct., flint varieties having a larger proportion of cob to grain than does dent corn. The cobs carry about 30 per ct. of fiber, which at best is of low feeding value, and much of their nitrogen-free extract is in the form of pentosans. (9) Since the cobs have some nutritive value, under certain conditions it is profitable to grind the whole ear into corn-and-cob meal. (208) Manifestly it is not economical to purchase ground corn cobs in adulterated commercial feeds at a price that would buy good concentrates. (285)

204. Shrinkage of ear corn.—While the amount of water in old corn varies but little from 12 per ct., the Iowa Station[1] found as high as 36 per ct. in freshly husked ear corn. Rarely will corn carrying 20 per ct. or more of water keep if stored in any considerable quantity. Studies conducted by the Kansas Station[2] with 3 lots of ear corn fairly dry when cribbed, others by the Illinois Station[3] with 2 cribs, each containing 20,000 lbs., and an 8-year test by the Iowa Station[4] show the following results:

Shrinkage in ear corn during storage

	Nov. and Dec. Per ct.	Nov. to Mar. Per ct.	Nov. to Apr. Per ct.	In 1 year Per ct.	In 2 years Per ct.
Kansas........	...	3.3	6.8	8.6	....
Illinois........	2.6	6.0	17.8	19.4	20.6
Iowa..........	6.9	9.7	12.8	18.2	....

In a year the corn in the Kansas trial shrank only 8.6 per ct. while that in the Iowa trial shrank 18.2 per ct. The rate of shrinkage depends not only on the maturity of the corn when husked, but also on the moisture content of the air. When the water content of ear corn falls to 12 per ct., shrinkage practically ceases. A large part of the shrinkage of ear corn is in the cobs, which usually form about one-fourth of the weight of the ears at husking and one-fifth of their cured weight. Twisting the ears slightly will fairly indicate the moisture contained. Loose grained, "sappy" ears carry 20 per ct. or more of water, while solid ones usually contain not much over 12 per ct. Seventy lbs. of dry dent corn of good varieties will make 1 bushel, or 56 lbs., of shelled corn, but in early fall the buyers frequently demand 75 or 80 lbs., according to the estimated water content. According to the Federal corn grades, by which corn is sold on the large markets, the percentage of water in corn must not exceed for Number 1, 14 per ct.; Number 2, 15.5 per ct.; Number 3, 17.5 per ct.; Number 4, 19.5 per ct,; Number 5, 21.5 per ct.; and Number 6, 23 per ct. Corn is stored mostly on the husked ear in the North, but in the South the husks are left on the ears because of the weevil, a beetle that lives in the kernels unless they are protected. Shelled corn does not keep well in bulk, especially in summer, and so corn is held in ear form as long as possible.

205. Soft corn.—Corn frosted before the grains mature contains too much water for storage or shipment, and is best utilized by immediate

[1]Iowa Bul. 77. [2]Kan. Bul. 144. [3]Ill. Bul. 113. [4]Hoard's Dairyman, 49, 463.

feeding. Soft corn has been fed successfully to swine (**940**), and for steers a pound of dry matter in soft corn containing 35 per ct. of water is equal in feeding value to a pound of dry matter in hard corn. (**737**)

A late-maturing variety of corn should not be planted in a locality having a short growing season, with the hope of getting a larger yield. The corn will usually not mature, there is great danger of its heating and molding, and the shrinkage is large. It is also difficult to secure seed for the following year which will retain its vitality.

206. Composition of the corn kernel.—To determine the composition of the different parts of the corn kernel, Hopkins of the Illinois Station[5] separated the kernels of an ear of average dent corn into their several parts and analyzed each. The weights of each part and the nutrients contained therein for 100 lbs. of water-free corn are shown in the following table:

Location of nutrients in the water-free corn kernel

	Total wt. in 100 lbs. corn Lbs.	Crude protein Lbs.	Carbo-hydrates Lbs.	Fat Lbs.	Ash Lbs.
Hull and tip cap......	7.39	0.36	6.88	0.08	0.07
Hornlike gluten......	8.51	1.89	5.88	0.59	0.15
Hornlike starch.......	47.08	4.80	42.05	0.11	0.11
Floury starch........	25.49	2.00	23.36	0.06	0.07
Germ...............	11.53	2.28	4.09	4.02	1.14
Whole kernel.......	100.00	11.33	82.26	4.86	1.54

In 100 lbs. of water-free corn the hulls and tip caps together weighed 7.39 lbs., the hornlike layer of gluten just under the skin 8.51 lbs., and the flinty, hornlike starch at the sides and base of the kernel 47.08 lbs., or nearly one-half of the total weight. In each 100 lbs. of kernels the soft, floury starch in the middle portion of the kernel formed 25.49 lbs. and the germ 11.53 lbs. The last 4 columns of the table show the number of pounds of each nutrient contained in each of the several parts of 100 lbs. of water-free corn. It is seen that the hull and tip cap are largely carbohydrates, while the germ is heavily charged with crude protein and fat, or oil.

Appendix Table I shows that air-dry dent corn contains 70.9 per ct. nitrogen-free extract—nearly all starch—and only 2.0 per ct. fiber, which comprises the fiber of the hull, or skin, of the kernel, and of the cell walls inclosing the starch grains. On comparing the composition of corn with that of the other common cereals, it will be noted that corn is by far the richest in fat, containing 5.0 per ct. fat, or oil. Because of this abundance of starch and oil, corn excels as a fattening food. Corn has slightly less crude protein than wheat, barley, oats, or rye and is also lower in ash. It is especially deficient in lime, containing only 0.2 lb. per 1,000 lbs. of grain. As has been emphasized before (**201**), in feeding corn we must bear in mind these facts concerning its composition.

[5] Ill. Bul. 87.

207. Corn meal; corn chop; corn feed-meal.—The term *corn meal,* as applied to feeding stuffs, is most correctly used to denote the entire ground corn grain, from which the bran or hulls have not been removed by bolting. In preparing corn for human food the grain is either ground to a rather coarse meal or cracked coarsely, the fine siftings and also the bran or hulls being removed. The milled product, which is likewise called corn meal, has a more attractive appearance than the entire ground grain, but contains somewhat less protein and fat. Much of the commercial corn meal, particularly in the Mississippi valley, is made from the part of the kernel left after the manufacture of cracked corn or table meal. It is most correctly called *corn feed-meal,* and according to Smith and Beals of the Massachusetts Station,[6] is equal in feeding value to corn meal made from the entire grain. *Corn chop* is a name sometimes applied to ground corn, and also to mixtures of ground corn and corn by-products. Since it has often been found best not to grind corn for stock (**423, 475, 735, 847, 921**), the question whether this grain should be reduced to a coarse or a fine meal has lost much of the interest once taken in it. On grinding corn the oil it carries soon becomes rancid and gives the meal a stale taste. Hence this grain should never be ground far in advance of use.

208. Corn-and-cob meal.—When ear corn is ground the product is called corn-and-cob meal. Because of the rubber-like consistency of the cobs, much power is required to reduce ear corn to meal. If the cob particles in corn-and-cob meal are coarse, the animal will not usually eat them, but when finely ground corn-and-cob meal proves satisfactory with most farm animals. (**576, 941**) Much evidently depends on the nature of the roughage fed with the meal. The Paris Omnibus Company found corn-and-cob meal more acceptable than pure corn meal to its thousands of horses (**475**), and stockmen generally report favorably on its use. It has been suggested that corn meal when fed alone lies too compactly in the stomach to be readily attacked by the digestive fluids, while corn-and-cob meal forms a loose mass more easy of digestion. Where there is an abundance of cheap roughage, it is best to omit the cobs in grinding unless there is ample power at low cost.

209. Starch and glucose by-products.—In the manufacture of commercial starch and glucose from corn, the grain is first passed thru cleaning machinery. It is then soaked in warm water, slightly acidulated with sulfurous acid, which softens the grain and facilitates the separation of the germ. Next the grain is coarsely ground and the mass passed into tanks containing "starch liquor." Here the germs, which are lighter on account of the large amount of oil they carry, rise to the surface, and are removed. After washing, the residue is then finely ground, and the coarser part, the bran, separated by silk sieves. The remainder, called "starch liquor," which contains the starch, gluten, and fine particles of fiber, is then passed slowly thru shallow, slightly inclined troughs where

[6] Mass. Bul. 146.

the starch settles like wet lime, while the lighter ingredients—the gluten, fiber, etc.—are carried off in the current of water. In this process there are thus obtained, (1) the germ, from which corn oil and germ oil meal or corn oil cake are secured, (2) the bran, consisting of the hulls, (3) the starch, and (4) the gluten. The bran, together with some light weight and broken germs, was formerly dried and sold as *corn bran.* Now, however, the bran and gluten are usually united while still wet, and then dried and ground, the product being sold as *corn gluten feed,* or *corn starch by-product with corn bran,* as it is sometimes called.[7] The term *corn gluten feed* is used to distinguish this feed from "Continental Gluten Feed," a proprietary name for certain dried distillers' grains. **(282)**

210. Corn gluten feed.—Formerly, the steep water, which contains the soluble materials, such as soluble protein and phosphates, was allowed to run to waste. It is now often evaporated and the residue, called corn solubles, is added to the gluten feed. Gluten feed is rich in crude protein, contains a fair amount of carbohydrates and fat, and is bulkier than corn. The protein content varies from 18 to over 29 per ct., depending chiefly on how completely the starch has been removed. The ash content ranges from less than 1 per ct. when the corn solubles have not been added to 5 or 6 per ct. when this residue has been incorporated. Owing chiefly to the acid nature of some of the protein and phosphorus compounds naturally occurring in the corn solubles, gluten feed to which these have been added has an acid taste unless the acid has been neutralized in the process of manufacture. While the small amount of acid present is probably not injurious to live stock, the feed is more palatable when the acidity is neutralized.

In early years gluten feed was normally yellow, since it was usually made from yellow corn. When manufacturers began to use white corn the resulting product had an uninviting grayish-white color, and was sometimes refused by purchasers. The manufacturers thereupon added artificial coloring matter to maintain the standard color. Tho the little coloring matter used is probably not injurious, it certainly adds nothing of value to the feed. Fortunately purchasers are learning to be governed by the guarantee and the taste, rather than by the color, and some manufacturers are hence discontinuing the coloring of this feed. Gluten feed is a most valuable concentrate, especially in the ration of the dairy cow. **(590, 757, 856)**

211. Gluten meal.—This by-product, now sometimes called *corn by-product without corn bran,* is one of the richest of concentrates in crude protein and fat, while fair in carbohydrates and low in mineral matter. It is a heavy feed, and, as mentioned before, is usually mixed with corn bran to form gluten feed. **(491, 591, 981)**

212. Germ oil meal.—The corn germs removed in the manufacture of starch are dried, crushed, and much of the oil pressed out, leaving the

[7] Wagner, U. S. Dept. Agr., Bur. Chem., Bul. 122, 1909; Lindsey, Mass. (Hatch) Bul. 78.

residue in cakes. This is exported as *corn oil cake,* or ground and sold in this country as *germ oil meal* or *corn germ meal.* This feed contains somewhat less protein than the usual gluten feed, but carries a much larger amount of fat. (**592**)

213. Hominy feed, meal, or chop.—This by-product, variously called *hominy feed, hominy meal,* or *hominy chop,* is a mixture of the bran coating, the germ, and a part of the starchy portion of the corn kernel obtained in the manufacture of hominy grits for human consumption and of brewers' grits. It is a carbonaceous feed, similar in composition to corn, but somewhat bulkier. It is slightly lower in nitrogen-free extract, higher in fiber, and contains much more fat. While slightly less digestible than corn meal, it is kiln-dried, almost invariably sweet, and keeps better in storage than does corn meal. As it is a bulkier feed than corn meal it is preferred for dairy cattle and has also proven superior to corn meal for fattening pigs. Cochel of the Kansas Station[8] reports that fattening calves would not eat as heavy an allowance of hominy feed as of corn meal, perhaps owing to the larger amount of oil in the hominy feed. (**577, 749, 943**)

214. Corn bran.—But little corn bran now comes upon the market as such, for, as we have seen, it is usually mixed with other by-products. (**209**) Corn bran contains about three-fifths as much protein as wheat bran, is somewhat higher than that feed in nitrogen-free extract and fat, and contains slightly more fiber.

II. Wheat and its By-products in Milling

Since it costs more to produce wheat, *Triticum sativum, tenax,* than corn, and since our population is steadily increasing, it is reasonable to suppose that wheat will never again be used in any considerable amount for feeding stock in this country, as it was at one time. But the feeder should know both its absolute and relative value, for the low grades of wheat would better be fed to stock than sold.

215. Wheat as a feed.—Compared with corn, wheat carries slightly more carbohydrates in the form of starch, more crude protein, and much less fat. Tho low in mineral matter, it contains somewhat more lime, phosphoric acid, and potash than corn. While the nutritive ratio of dent corn is 1:10.4, that of wheat is 1:7.7. Tho wheat thus carries a larger proportion of protein, this nutrient is unbalanced in composition, like that of corn. (**118**) Probably due to this, Hart, McCollum, and Fuller[9] have found in trials at the Wisconsin Station that pigs fed on wheat as the sole source of protein for long periods are unable to make normal growth, even when an abundance of mineral matter is supplied. (**105**) Like corn, wheat should be supplemented by feeds rich in protein and lime. Fed in properly balanced rations wheat is about equal to corn for milk production or for fattening animals. (**578, 739, 849, 945**) Fed

[8]Kansas Industrialist, 41, 1915. [9]Jour. Biol. Chem., 19, 1914, pp. 373-395.

in large amounts to horses it has occasioned digestive disturbances and eruptions of the skin. (**479**) Because the kernels are small and hard, wheat should be ground for all farm animals except sheep. Wheat flour and meal fed alone are unsatisfactory because they form a pasty mass in the animal's mouth, a condition which can be remedied by adding some such material as bran or coarse corn meal. (**423**)

As stated before (**81**), the composition of the wheat kernel is markedly influenced by climate, especially in protein content. Wheat from the northern plains region is highest in crude protein, while that from the Pacific coast districts is unusually low in this nutrient. When grown under the same climatic conditions spring wheat is usually slightly richer in crude protein than winter wheat.[10] Durum, or macaroni, wheat is extensively grown in parts of the plains states, especially the Dakotas, on account of its higher yield in these sections. This variety shows no appreciable difference in composition or feeding value from ordinary wheat grown under the same environment.[11] (**849**)

Wheat growers should sell only the best grades, retaining for their animals all shrunken, frosted, or otherwise damaged grain, for while such wheat has low selling value, it is often equal to grain of good quality for feeding. (**739, 849, 945**) As a rule such grain is richer in protein than is wheat of good quality.

Salvage grain, which has been slightly charred or injured by smoke and water in elevator fires, thus being unfitted for human food, may have its value for stock feeding but little impaired.

216. Flour manufacture.—The wheat kernel is covered with three strawlike coats or skins. Beneath these comes the fourth, called the "aleurone layer," rich in crude protein, and which in milling goes with the other coats to form bran. The germ, or embryo plant, in each kernel is rich in oil, crude protein, and mineral matter. The remainder of the kernel consists of thin-walled cells packed with starch grains. Among the starch grains are protein particles called "gluten," that give wheat-flour dough the tenacity so essential in bread making. In producing flour the miller aims to secure all the starch and gluten possible from the wheat grains, while avoiding the germ and bran. He leaves out the germs because they make a sticky dough and also soon turn dark and rancid, giving the flour a specked appearance. Nor does he use the aleurone layer, as it gives a brownish tint to the flour.

In modern milling, flour is produced by passing the thoroly cleaned wheat thru a series of hardened steel rollers, each succeeding pair being set a little nearer together so that the kernels are gradually crushed into smaller and smaller particles. After passing thru each pair of rollers, or "breaks," the flour is removed by sifting or passing the material over bolting cloth, and finally only the by-products remain.

The terms employed to designate the various mill products differ somewhat in various sections of the country, but those most commonly used

[10] Bailey, Minn. Bul. 143. [11] Ladd and Bailey, N. D. Bul. 93.

are *wheat bran, standard middlings* or *shorts, white* or *flour middlings, red dog flour* and *wheat mixed feed.*

In the manufacture of flour, from 25 to 33 per ct. of the weight of the wheat grain remains as bran, middlings, etc. Since the annual consumption of wheat in this country is about 4.5 bushels, or 270 lbs., for each person, the by-products of this grain amount to nearly 70 lbs. for each person, not including that resulting from the wheat milled for export.

217. Feeding bread.—When available, the stale bread from bakeries is used for feeding animals, especially horses. Gay[12] states that a Philadelphia teamster fed stale bread mixed with molasses, at a considerable saving and with entire success. An English writer[13] also reports good results from feeding bread to cab horses in London, the only trouble being that many loaves were consumed by the workmen.

218. Wheat bran.—Bran, which consists of the coarse outer coatings of the wheat kernel, is comparatively rich in digestible crude protein, carries considerable digestible carbohydrates and fat, and is high in mineral matter, except lime. It is light and chaffy, carrying a considerable amount of fiber. Bran from mills lacking machinery for perfect separation of the starch from the bran coats is somewhat lower in crude protein and fiber and higher in carbohydrates than the bran from the large mills. Woll[14] concludes that the nutritive difference is usually small, making it advisable to select whichever is cheaper.

Hart and Patten of the New York (Geneva) Station[15] have shown that ordinary wheat bran contains from 6 to 7 per ct. of an organic compound containing phosphorus, magnesia, and potash. In the past the laxative effect of bran, one of its beneficial properties, was ascribed to the mild irritation produced by the chaffy bran particles on the lining of the intestinal tract. These chemists have found, however, that the laxative effect of bran is due to this phosphorus compound. Phosphorus, an essential component of the bones and of milk, is abundant in bran, while lime, likewise needed in still larger amount, is but sparingly present. Horses heavily fed on wheat bran or middlings sometimes suffer from "bran disease,"[16] which seriously affects their bones. To supply the lime which bran lacks, farm animals may be fed lime in inorganic form—wood ashes, ground limestone, burned lime, or ground rock phosphate (floats), or they may be supplied lime in organic form by feeding lime-laden plants, such as the legumes, which include alfalfa, clover, vetch, cowpea, etc. (**98**) The best grades of bran are of light weight, with large, clean flakes and no foreign matter.

Knowing the properties of bran, one is in position to use this most

[12]Productive Horse Husbandry, p. 239.
[13]The Field, England, July 15, 1893.
[14]Productive Feeding of Farm Animals, p. 180.
[15]N. Y. (Geneva) Bul. 250.
[16]Law's Vet. Medicine, III, p. 572.

valuable feed advantageously. As bran is ordinarily too expensive to be used as the sole concentrate for farm animals, it should be mixed with other concentrates to lighten the ration or add bulk while improving its nutritive qualities. Fairly high in protein and rich in phosphorus, it serves its highest purpose in giving virility to the animal and in helping build bone and muscle without tending to fatten, thus being especially suited to young animals whose digestive capacities are sufficiently developed for this bulky feed. (**523, 681, 894**) Both on account of its high content of crude protein and phosphorus and because of its laxative action, bran is of great value in putting the bodies of pregnant mares, cows, ewes, or sows in the best condition for bearing young. (**514, 673-4, 883, 1015**) Supplied to horses once or twice a week in the form of a "mash" made with scalding water, bran proves a mild, beneficial laxative. (**486**) When used continuously, the animal system becomes accustomed to it and the laxative property is less marked. Hard-worked horses have neither time nor energy to digest feeds of much bulk, and hence their allowance of bran should be limited. (**457, 486**) Being bulky, bran is often mixed with corn and other heavy concentrates for starting fattening cattle or sheep on feed. (**756, 856**) It is a most excellent feed for the dairy cow, being slightly laxative, giving bulk to the ration, and providing the crude protein and phosphorus so vital to the formation of milk. (**588**) Tho too strawlike for young pigs, it is valuable for giving bulk and nutriment to the ration for breeding swine and stock hogs not getting legume pasture or hay. (**972**)

Due to its widespread popularity, bran is often high in price compared with other nitrogenous concentrates which can be used with equally good results and many of which carry more protein than does bran.

219. Red dog flour.—Red dog flour, or dark feeding flour, generally contains the wheat germs and is therefore rich in crude protein and fat. Such flour differs but little in composition and feeding value from the best flour middlings. (**971**)

220. Wheat middlings.—Middlings vary in quality from red dog flour, which contains considerable flour, to standard middlings, or shorts, which may contain but little flour. To some extent *standard* or *brown middlings* and *shorts* are interchangeable terms. Standard wheat middlings comprise the finer bran particles with considerable flour adhering. Shorts too often consist of ground-over bran and the sweepings and dirt of the mills, along with ground or unground weed seeds. *Flour* or *white middlings* are of somewhat higher grade than standard middlings; containing considerable low-grade flour and carrying slightly more crude protein and less fiber. Middlings are highly useful with swine of all ages. They should not be fed alone, but always with more carbonaceous feeds, as corn or barley. (**969-70**) Mixed with the various ground grains, middlings and shorts are helpful with dairy cows, since they add crude protein and phosphorus to the ration. (**589**) Middlings and shorts alone should never be fed to horses, since they are too heavy and pasty in character and are liable to induce colic. (**487**) Like bran, both middlings and shorts are low in lime, which should always be supplied by the other feeds in the ration.

221. Wheat mixed feed.—*Wheat mixed feed,* or *shipstuff,* is, strictly speaking, the entire mill run of the residues of the wheat kernel left after separating the commercial flour. The term is also used for various mixtures of bran and red dog flour or middlings. Smith and Beals of the Massachusetts Station[17] state that a good grade is superior to wheat bran, but that a difference of 10 per ct. in value is often noted in different samples, depending on the amount of flour contained.

222. Screenings.—In cleaning and grading wheat at the elevators and mills, there remain great quantities of screenings, consisting of broken and shrunken wheat kernels having a high feeding value, mixed with weed seeds. Many of the latter are nutritious, while others are of little worth, and a few actually poisonous. Poisonous seeds, such as corn cockle, are rarely present in screenings in sufficient quantities to cause ill effects. Unground screenings will never be used by farmers who seek to keep their land free from noxious weeds, for many such seeds will pass thru the animals uninjured and be carried to the field in the manure. Finely ground screenings are free from this objection. Screenings have their place and use, tho, because of their variable character, little of a definite nature can be said concerning them. (**850, 954**) Along with molasses and the by-products of the distilleries, breweries, flouring mills, oatmeal factories, etc., they are now largely absorbed in the manufacture of proprietary feeding stuffs. (**285**)

The feed control laws of various states require that when screenings are present in feeds the fact be indicated on the label and in some cases the percentage must be stated. *Wheat bran with mill run screenings* is a trade term for pure wheat bran plus the screenings which were separated from the wheat whence the bran originated. *Wheat bran with screenings not exceeding mill run* may be either wheat bran with the whole mill run of screenings or with but a portion of the screenings output.

III. Oats and their By-products

Next to corn, oats, *Avena sativa,* are the most extensively grown cereal in America. In the southern portion of our country a bushel of oats often weighs only 20 lbs., while on the Pacific coast it may weigh 50 lbs. Southern oats have a larger kernel than the northern grain, but bear an inflated husk carrying an awn or beard, which causes the grains to lie loosely in the measure. In the North the kernel is encased in a compact hull, usually not awned. The hulls of oats constitute from 20 to 45 per ct. of their total weight, the average being about 30 per ct. "Clipped oats" have had the hulls clipped at the pointed end, thereby

[17] Mass. Bul. 146.

increasing the weight per bushel. A hulless oat, but little grown in this country, serves well for poultry and swine, while the varieties with hulls are preferable for other stock. The oat grain is higher in crude protein than is corn, and in fat it exceeds wheat and nearly equals corn.

223. Oats as a feed.—Oats are the safest of all feeds for the horse, for the hull gives them such volume that the animal rarely suffers from gorging; in this respect they are in strong contrast with corn. On account of the mettle so characteristic of the oat-fed horse, it was long held that there is a stimulating substance in the oat grain. All claims of the discovery of this compound have, however, melted away on careful examination, and rations containing no oats have given results in every way as good as where oats were fed. (**473-4**) For dairy cows there is no better grain than oats, but their use is restricted by their high price. (**579**) Oats mixed with other concentrates are helpful in starting fattening cattle or sheep on feed. As fattening progresses more concentrated feeds should be substituted for all or most of the oats. (**740, 851**) Ground oats with the hulls sifted out provide a nourishing and wholesome feed for young calves and pigs. (**946**) For breeding swine, whole oats in limited quantity are always in place. As light weight oats contain more hull and less kernel than plump, heavy oats, their feeding value per pound will be correspondingly less.

In recent years the bleaching of low-grade oats and barley with sulfurous acid fumes to whiten the grain and raise the market grade, has become common. Smith[18] estimates that in 6 months beginning October 1, 1908, nearly 19,000,000 bushels of oats and barley were bleached at 13 grain centers in 3 north-central states. No feeding trials have been reported in which *bleached oats* have been fed, but complaints from horsemen of injurious effects on the health of the animals fed such oats are not uncommon. Several states have laws regulating the sale of bleached grains.

224. Oat by-products.—In the manufacture of oatmeal and other breakfast foods, after the light-weight grains are screened out to be sold as feed the hulls are removed from the remainder, a vast quantity resulting. So completely are the kernels separated that the chaff-like hulls have but low feeding value. Oat hulls contain about 30 per ct. fiber, as Appendix Table I shows, and their feeding value is only little, if any, above that of oat straw. If fragments of the kernels adhere, their value is of course thereby improved. The oat hulls are sold in mixture with other feeds under various names. (**285**) The statement of feed manufacturers that the addition of a limited amount of hulls to a heavy concentrate mixture is beneficial seems reasonable in view of the excellent results secured with the natural unhulled oats. However, the appearance of such feeds is no guide to their value or the quantity of hulls present, and they hence should be purchased only on guarantee and on the basis of their actual composition compared with standard feeds.

[18]U. S. Dept. Agr., Bur. Plant Indus., Cir. 74.

After the oats are hulled, they are freed from the minute hairs which adhere to the outer end of the kernel. Small as these hairs are, they form with fragments of the kernels a product of great volume, known as *oat dust,* which contains considerable protein and fat, with about 18 per ct. fiber. This feed is usually sold in mixture with other concentrates, as its light, fluffy nature makes it unsuitable to feed alone. In feeding value this product ranks between oat hulls and oat middlings. *Oat shorts* or *middlings,* consisting of the outside skins of the kernels, closely resemble wheat bran in composition, but carry more fat. *Oat feeds* are mixtures, widely varying in composition, of ground oat hulls, oat middlings, and other by-products. Since the feeding value will depend on the amount of hulls present, these feeds should be purchased only on guarantee of composition and from reputable dealers. The fiber content of any lot indicates the relative amount of hulls contained. *Clipped oat by-product,* or *oat clippings,* is the by-product obtained in the manufacture of clipped oats. This material, which consists of chaffy material broken from the ends of the hulls, empty hulls, light immature oats, and dust, is used in various proprietary feeds.

225. Ground corn and oats.—This feed, variously called *ground corn and oats, ground feed,* and *provender,* is extensively employed in the eastern and southern states for feeding dairy cows and especially horses. In composition it ranges from a straight mixture of good-grade corn and oats to one containing a large proportion of low-grade materials such as oat hulls, ground corn cobs, and other refuse. The best guide to the purity of this feed is the fiber content. As corn contains only 2.0 per ct. fiber and oats 10.9 per ct., when ground corn and oat feed contains over about 7 per ct. fiber, it has either been adulterated or was made from poor quality oats. Where more than 9 per ct. fiber is present adulteration is certain.[19] This feed should be purchased only on guarantee and from reliable dealers.

IV. Barley and its By-products in Brewing

Barley, *Hordeum sativum,* is the most widely cultivated of the cereals, growing as far north as 65° north latitude in Alaska and flourishing beside orange groves in California. Once the chief bread plant of many ancient nations, it is now used almost wholly for brewing, pearling, and stock feeding. Richardson[20] found that Dakota barley contained the highest percentage of crude protein, and Oregon barley the lowest. The adherent hull of the grain of ordinary brewing barley or of Scotch barley constitutes about 15 per ct. of its total weight.

California feed barley, grown extensively in some sections of the West, has more hull and weighs 45 lbs. or less per bushel; while the usual weight of common barley is 48 lbs. Bald, or hulless, barley also grown in the western states has hard kernels, contains less fiber owing to the

[19] Woll and Strowd, Wis. Cir. 47. [20] U. S. Dept. Agr., Div. of Chem., Bul. 9.

absence of the hull, and is as heavy as wheat. (**848**) Barley has less digestible crude protein than oats, and more than corn. The carbohydrates exceed those of oats and fall below those in corn, while the oil content is lower than in either of these grains.

226. Barley as a feed.—On the Pacific slope, where corn or oats do not flourish in equal degree, barley is extensively used as a feed for animals. The horses of California are quite generally fed on rolled barley, with wheat, oat, or barley hay for roughage. (**494**) Barley is the common feed for dairy cows in northern Europe. The Danes sow barley and oats together in the proportion of 1 part of barley to 2 of oats, the ground mixed grain from this crop being regarded as the best available feed for dairy cows and other stock. (**580**) Fed with legume hay to fattening steers and lambs, barley has given nearly as good returns as corn. (**738, 848**) For horses barley is somewhat less valuable than oats. (**478**) At the Virginia Station[21] calves made excellent gains on barley and skim milk, but corn proved cheaper. (**681**) In Great Britain and northern Europe barley takes the place of corn for pig feeding, leading all grains in producing pork of fine quality, both as to hardness and flavor. In American trials somewhat more barley than corn has been required for 100 lbs. gain with fattening pigs. (**944**) Owing to its more chaffy nature California feed barley is somewhat lower in value than common barley. (**848**) Tho barley is somewhat higher than corn in crude protein, it is still decidedly carbonaceous in character, and should be fed with legume hay or with a nitrogenous concentrate for the best results.

227. Malt.—In making malt the barley grains are first steeped in warm water until soft. The grain is then held at a warm temperature until it begins to sprout, in which process the amount of diastase, the enzyme which converts starch into malt sugar, increases greatly, and some of the starch in the grain is acted on by the diastase. When sufficient diastase has been formed in the sprouting grain, it is quickly dried. The tiny, dry, shriveled sprouts are then separated from the grains, and put on the market as *malt sprouts.* The dried grains remaining form *malt.* In the manufacture of beer the malt, after being crushed by rolling, is moistened and usually mixed with cracked corn which has been previously cooked. The diastase in the malt now converts the starch in the corn and the malt itself into malt sugar. This, together with some of the nitrogenous and mineral matter is then extracted from the mass and fermented by yeast. The freshly extracted residue constitutes *wet brewers' grains,* which on drying in a vacuum are called *dried brewers' grains* or *brewers' dried grains.*

It was formerly claimed that malting barley increased its value for stock feeding. Investigations by Lawes and Gilbert of the Rothamsted Station,[22] England, show that a given weight of barley is of greater value for dairy cows and fattening animals than the amount of malt and malt sprouts that would be produced from it. This is due to the oxidizing

[21] Va. Bul. 172.

[22] Rothamsted Memoirs, Vol. IV.

or burning up of some of the stored nutrients in the grain during the sprouting process. Malt is, however, very palatable to stock, and useful as a conditioner and in fitting animals for exhibition or sale.[23]

228. Dried brewers' grains.—Dried brewers' grains, which are no more perishable than wheat bran, contain over 70 per ct. more digestible crude protein and twice as much fat as wheat bran, but are lower in carbohydrates, which are largely pentosans.[24] (**9**)

Higher in fiber than wheat bran, they are a bulky feed, and therefore not well suited to pigs. They are widely fed to dairy cows and serve well as part of the concentrate allowance for horses, especially for those at hard work, and needing an ample supply of protein. (**488, 593, 759, 856**)

229. Wet brewers' grains.—Owing to their volume, watery nature, and perishable character, wet brewers' grains are usually fed near the brewery. Containing about 75 per ct. water, they have slightly over one-fourth the feeding value of an equal weight of dried grains. In the hands of ignorant or greedy persons cows have often been crowded into dark, illy-ventilated sheds and fed almost exclusively upon wet brewers' grains. Sometimes the grains are partially rotted when fed, and the drippings getting under feed boxes and floors produce sickening odors. It is not surprising that boards of health have prohibited the sale of milk from such dairies. There is nothing in fresh brewers' grains which is necessarily deleterious to milk. Supplied in reasonable quantity, 20 to 30 lbs. per head daily, and fed while fresh in clean, water-tight boxes and along with nutritious hay and other roughage, there is no better food for dairy cows than wet brewers' grains. So great is the temptation to abuse, however, that wet grains should never be fed to dairy cows unless under the supervision of competent officials. If this cannot be done, their use should be prohibited. In Europe the wet grains are considered excellent for fattening cattle and swine when used with dry feed and furnishing not over half the nutrients in the ration. On account of their "washy" nature, they are not so useful for horses and sheep, tho horses may be fed 20 lbs. per head daily and fattening sheep 1 lb. daily per 100 lbs. live weight.[25]

230. Malt sprouts.—The tiny, shriveled sprouts which have been separated from the dried malt grains form a bulky feed which is rather low in carbohydrates and fat, but carries about 20 per ct. digestible crude protein, one-third of which is amids.[26] At ruling prices they are an economical source of protein, but not being relished by stock should be given in limited quantity mixed with other concentrates. Malt sprouts are especially valuable for dairy cows, tho they will not usually eat over 2 or 3 lbs. daily. (**594**) In Europe horses have been fed as high as 5 to 6 lbs.

[23] Pott, Handb. Ernähr. u. Futter., III, 1909, p. 257.

[24] Mass. (Hatch) Bul. 94.

[25] Pott, Handb. Ernähr. u. Futter., III, 1909, p. 233.

[26] Pott, Handb. Ernähr. u. Futter., III, 1909, p. 223.

per head daily with good results, and sheep 0.5 lb. daily per 100 lbs. live weight. Since malt sprouts swell greatly when they absorb water, they may cause digestive disturbances if fed dry to stock in large amounts and should therefore be soaked for several hours before feeding. When not over 1 lb. per head is fed to cattle with other feed, soaking is unnecessary, but moistening to lay the dust is advisable.[27]

231. Barley feed.—This by-product from the manufacture of pearl barley or flour has about the same feeding value as wheat bran, being somewhat lower in protein and higher in nitrogen-free extract.

V. Rye and its By-products

Rye, *Secale cereale,* the principal cereal of north Europe, is not extensively grown in America. Tho it repays good treatment, this "grain of poverty" thrives in cool regions on land that would not give profitable returns with the other cereals. It furnishes about one-third of the people of Europe with bread, and when low in price or off-grade is commonly fed to stock. (**396**)

232. Rye and its by-products.—Tho farm animals show no fondness for rye, they take it willingly when mixed with other feeds, as should always be done. Fed alone or in large amounts it is more apt to cause digestive disturbances than the other cereals. In northern Europe it is a common feed for horses and swine. (**480, 948**) Fed in large allowance to cows rye produces a hard, dry butter, but a limited amount mixed with other feeds has given good results. (**581**)

The by-products in the manufacture of rye flour are *rye bran* and *rye middlings,* which are usually combined and sold as *rye feed.* All have about the same feeding value as the corresponding wheat feeds, each containing less fiber and being somewhat lower in protein and higher in nitrogen-free extract than the corresponding wheat feed.

VI. Emmer

Emmer, *Triticum sat.,* var. *dicoccum,* often incorrectly called "spelt" or "speltz," was introduced into America from Germany and Russia. It is a member of the wheat family, altho in appearance the grain resembles barley. Being drought resisting, emmer is especially valuable in the semi-arid regions of America. In 1909, 12,700,000 bushels were grown, mostly in the northern plains states, the average yield per acre being 22 bushels of 40 lbs. each. The adherent hulls of emmer represent about 21 per ct. and the kernels 79 per ct. of the grain.

The following table shows the average yields of various spring grains grown without irrigation for 8 years at the North Dakota Station at Fargo[28] and for 5 years at the North Platte, Nebraska, Station:[29]

[27] Pott, Handb. Ernähr. u. Futter., III, 1909, p. 226.

[28] N. D. Bul. 75. [29] Nebr. Bul. 135.

Yield of emmer compared with other spring grains

Grain	North Dakota Yield per acre Lbs.	Nebraska Yield per acre Lbs.
Emmer	1,945	1,142
Barley	1,877	1,423
Oats	1,969	1,032
Wheat	1,711	.....
Durum wheat	1,835*	1,151

* Av. of 7 years.

Winter emmer, introduced more recently into the United States, is of considerable promise in states where it is hardy.[30]

233. Emmer as a feed.—In composition emmer closely resembles oats. Like that grain it is somewhat bulky to use as the sole concentrate for fattening animals, and gives better results when mixed with corn or barley. (**852**) Tho its value is usually somewhat lower than that of corn, with corn silage and linseed meal, ground emmer proved equal to corn, pound for pound, with fattening steers in a trial at the South Dakota Station. (**743**) With dairy cows and fattening pigs its value is somewhat less than that of corn. (**582, 947**) Thru the introduction of emmer, kafir, milo, and certain millets, all relatively new plants with us, the possibilities of the great plains region of America for the maintenance of farm animals and the production of meat have been enormously increased.

[30]U. S. Dept. Agr., Farmers' Bul. 466.

CHAPTER X

MINOR CEREALS, OIL-BEARING AND LEGUMINOUS SEEDS, AND THEIR BY-PRODUCTS

I. Rice and its By-products

The production of rice, *Oryza sativa,* is steadily increasing in Louisiana, Texas, and Arkansas, where it already forms an important industry. In 1914 about 22,589,000 bushels of rice, over 95 per ct. of the entire crop of the United States, was produced in these states.[1] Like wheat, this cereal is used almost entirely for human food, only the by-products from the manufacture of table, or polished, rice being fed to farm animals.

234. Rice and its by-products.—In preparing *rough rice,* often called *paddy,* for human food, first the hulls and next the bran, or outer skin of the kernel, are removed. The kernels are then "polished," both to separate the creamy outside layer of cells, rich in crude protein and fat, and to produce an attractive, pearly luster. The resulting floury particles constitute *rice polish.* According to Fraps[2] of the Texas Station, a sack of rough rice, weighing 162 lbs., will yield about 100 lbs. of polished rice, 6.3 lbs. of rice polish, 20.2 lbs. of rice bran, and 32.1 lbs. of hulls, with a wastage of 3.4 lbs.

Rice hulls are tasteless, tough, and woody. They are heavily charged with silica, or sand, and have sharp, roughened, flinty edges and needle-like points which, not softening in the digestive tract, prove irritating and dangerous to the walls of the stomach and intestines. Because of authentic reports of vomiting and death with cattle fed rice hulls, they should never be fed to farm animals.[3] Yet rice hulls have been extensively employed by unscrupulous dealers for adulterating commercial feeding stuffs, and are sometimes ground and sold as "husk meal" or "Star bran."

Rice bran, when pure, is composed of the outer layer of the rice kernel proper, together with the germs, and a small amount of hulls not separated in the milling process. This feed, when adulterated with hulls, is called "commercial bran." Unadulterated bran, which does not contain over 12 per ct. fiber, is a highly nutritious feed, as not enough hulls are present to be injurious. It contains about 11 per ct. fat, and approximately as much protein as barley or wheat, but less nitrogen-free extract. As rice oil, or fat, soon becomes rancid, the bran is frequently distasteful to animals. The Louisiana Station employed rice bran successfully as half the concentrates for horses and mules, and it was found satisfactory

[1] U. S. Dept. Agr., Yearbook, 1914. [2] Tex. Bul. 73. [3] La. Bul. 77.

for fattening steers at the Texas Station. (**745**) Fed to dairy cows and swine in large amounts, even when not rancid, it injures the quality of milk and produces soft pork. (**980**)

Rice polish, which has a feeding value equal to corn, carries slightly more crude protein and considerably more fat, but correspondingly less nitrogen-free extract. Its use in the arts removes it largely from the list of farm feeding stuffs. (**745, 980**)

Only low-grade *rough rice* and *hulled rice* are commonly fed to stock. Dodson of the Louisiana Station[4] values rough rice at 7 and hulled rice at 16 per ct. more than corn. Hulled rice is the richest of all cereals in carbohydrates, but relatively low in crude protein and fat. Since no ill effects from the hulls have been known to follow the feeding of rough rice, it may replace corn in the rations of farm animals. On account of the hardness of the kernels it gives better results when ground. The Texas Station[5] found that ground damaged rice had about half the value of cottonseed meal for fattening steers. Red rice, a pest in rice fields, equals the cultivated grain in feeding value. (**745**)

II. Sorghums and Millets

Numberless millions of people in India, China, and Africa rely on the sorghums and millets for their bread. Church[6] tells us that 33,000,000 acres of land in India are annually devoted to growing the millets and the sorghums including the kafirs, milos, etc.—a greater area, he reports, than is devoted to wheat, rice, and Indian corn combined. Ball[7] writes that thruout Africa—on the dry plains, in the oases of the Sahara, on high plateaus, in mountain valleys, and in tropical jungles—the sorghums are the one ever-present crop. Their forms are as diverse as the conditions under which they grow, the plants ranging in height from 3 to 20 feet, with heads of different shapes varying from 5 to 25 inches in length.

The sorghums, *Andropogon sorghum* or *Sorghum vulgare,* vars., may be divided into two classes—the saccharine sorghums, having stems filled with sweet juices, and the non-saccharine varieties, with more pithy stems and juice sour or only slightly sweet. The Indian corn plant never gives satisfactory returns if once its growth is checked. The sorghums may cease growing and their leaves shrivel during periods of excessive heat and drought; yet when these conditions pass and the soil becomes moist again, they quickly resume growth. This quality gives to this group of plants great worth and vast importance as grain crops for the southern portion of the semi-arid plains region. Their value in this section is well shown by the fact that between 1899 and 1909 the acreage in the United States of kafir and milo grown for grain increased from 266,000 to 1,635,000 acres.

[4] La. Planter, 44, 6, p. 92.
[5] Tex. Bul. 86.
[6] Food Grains in India, 1901.
[7] Yearbook, U. S. Dept. Agr., 1913.

235. Grain sorghums.—The non-saccharine, or grain, sorghums include *kafir, durra, milo, feterita, kaoliang,* and the less important *shallu.* The *kafirs* are stout-stemmed, broad-leaved plants, having slightly sweet juice and long, erect, cylindrical heads carrying small, egg-shaped seeds. The true *durras* were the first grain sorghums introduced into the United States. They were never grown to any great extent as they have coarse stems, relatively few leaves, lodge readily, and sucker badly. The grain shatters easily and the pendent, or "goose-necked," heads render harvesting difficult.

The *milos,* sometimes classed under the durras, have few leaves compared with the kafirs, and hence are not as valuable for forage. They usually have short, thick heads with large, flat seeds. The heads are mostly goose-necked, but some strains have recently been developed in which nearly all the heads are erect. *Feterita,* or *Sudan durra,* has slender stems carrying more leaves than milo, but less than kafir, and erect heads bearing flattened seeds.

The *kaoliangs,* early maturing sorghums from northern China, are slender, dry-stemmed plants, with loose, open, erect heads. *Shallu,* or "Egyptian wheat," is slender-stemmed, with low, spreading heads which shatter badly. Reports from various experiment stations show that shallu is of little value compared with the other sorghums.

Most of the grain sorghum produced in the United States is grown in the southern part of the Great Plains region, east of the Rocky Mountains, extending from southwestern Nebraska to northwestern Texas. A limited amount is also grown in sections of Arizona, Utah, and California. By selection and crossing, varieties of sorghum are being developed which are suited to the various districts, especially dwarf strains which have erect heads that are easily harvested with the grain header, and which are early maturing, thereby escaping late summer droughts. Thru the development of early types the sorghums are being carried further north. Over much of the drier western portion of the grain-sorghum belt these crops are more sure, and, even on good soil, return larger yields than corn.

On poor, thin uplands in central and eastern Kansas and Oklahoma the sorghums are also superior to corn. Churchill and Wright[8] of the Oklahoma Station report that during the 5 years, from 1909 to 1913, on soil underlaid by hardpan where the average yield of corn was only 1 bushel per acre, kafir averaged 34.9 bushels. Even on better land in such districts it is advisable to replace some of the corn acreage with grain sorghum as an insurance against severe drought. Piper[9] states that the grain sorghums commonly yield 25 bushels per acre with maximums of 75 bushels for kafir, 46 for milo, and 80 for feterita.

The customary basis for selling the seed of the grain sorghums is by the 56-lb. bushel, but, according to Churchill and Wright[10] of the Oklahoma Station, the usual weight is about 54 lbs. Kafir heads contain about 77 per ct. of grain and those of milo about 84 per ct.; accordingly

[8] Okla. Bul. 102. [9] Forage Plants, p. 273. [10] Okla. Bul. 102.

73 lbs. of head kafir and 66 lbs. of head milo are required for a bushel (56 lbs.) of grain. Ball[11] states that altho the percentage of grain in the entire crop varies widely with the season and thickness of stand, under ordinary conditions from 35 to 40 per ct. of the air-dry weight of a crop of milo and kaoliang and 25 per ct. of kafir will be grain.

When cut for grain the crop should not be harvested until the seeds are well matured. Because the hard-coated seeds when apparently dry may contain much water, the grain sorghums are especially apt to heat in the bin unless precautions are taken.

236. Grain sorghums as feeds.—The different sorghums are similar in composition, carrying about as much crude protein and nitrogen-free extract as corn, but about 1.5 per ct. less fat. Properly supplemented with protein-rich feeds, they are excellent for all classes of animals. Tho less palatable than corn, their nutritive value ranges from fully equal to this grain to 15 per ct. less. (**741-2, 853, 949-51**) For horses, fattening cattle, dairy cows, and pigs the grain is usually ground, being then called "chop." Grinding for sheep is not essential. Often the unthreshed heads are fed, or the forage carrying the heads is supplied, especially to idle horses, colts, and young stock. (**481**) On grinding the entire heads the product is called "head chop," which resembles corn-and-cob meal in composition.

237. Kafir.—The kafirs lead in both grain and forage production in eastern Kansas and Oklahoma. This type does not sucker or produce undesirable side branches, has erect, compact heads, and neither lodges nor shatters its grain. The most common type in the more humid districts is the Blackhull while farther west the Dwarf Blackhull and the White are recommended as their earliness enables them the better to evade drought.[12] Grown in regions of deficient rainfall, the average yield of kafir is not large. In good seasons and on fertile soil yields of 50 bushels per acre, and occasionally 75 bushels, are secured. Kafir grain, being astringent and constipating, is suited for feeding with alfalfa, clover, and other somewhat laxative roughages. (**481, 583, 681, 741, 853, 949**)

238. Milo.—Next to kafir, milo is the most important of this class of plants. Grown but little in the extreme east of the grain belt, it outyields kafir in the more arid districts as it is earlier. According to Ball,[13] milo is somewhat superior to the kafirs as a feeding grain, and unlike the kafirs, has a beneficial laxative effect on the bowels. (**481, 742, 853, 950**)

239. Feterita.—This type of durra ripens with milo, but when both are planted late matures sooner. It yields as much grain as kafir, tho less forage, and is a most promising sorghum for the eastern portion of the grain sorghum belt. Unfortunately it stools badly and lodges easily after maturity.[14] (**870, 951**)

240. Kaoliang.—These early-maturing sorghums are of much promise for the northern plains section where the other types will not mature. The kaoliangs compare favorably in yield of grain with the milos, and

[11] U. S. Farmers' Bul. 448.
[12] Kan. Bul. 198.
[13] U. S. Farmers' Bul. 322.
[14] Okla. Bul. 102.

are even better in severe drought. Hume and Champlin report that in 1911 at the Highmore, South Dakota, Branch Station[15] when all the small grain crops were a failure because of drought, kaoliang yielded from 6 to 11 bushels per acre, small tho promising yields. The forage of the kaoliangs is scanty and of poor quality, the stalks being pithy and the leaves few. In sections where they mature, kafir, milo, or feterita are to be preferred. (**951**)

241. Sweet sorghums.—The sweet sorghums, or *sorghos,* are forage rather than grain producers, and are therefore discussed more fully in Chapter XII. (**308-9**) Early varieties will mature wherever corn ripens. At the Wisconsin Station[16] the senior author secured 32 bushels weighing 53 lbs. each of amber cane seed per acre. Cook of the New Jersey Station[17] found amber cane seed about 10 per ct. less valuable than Indian corn for dairy cows. (**584**) For grain production sweet sorghum is surpassed by corn in the humid regions and by the grain sorghums in the plains districts.

242. Broom corn.—In harvesting broom corn the heads are cut before the seed has fully matured, and the seed is removed from the brush before it is thoroly dry. This seed has feeding value and may be saved by drying or ensiling or, as Miles[18] showed, by preserving in an earth-covered heap.

243. Millets.—The millets chiefly grown in this country are: (1) the foxtail millets, *Setaria Italica* spp., all resembling common foxtail or pigeon grass in appearance; and, (2) the broom corn, proso, or hog millets, *Panicum miliaceum* spp., which have spreading or panicled heads, wide hairy leaves, and large seed. Other types used only for forage are mentioned in Chapter XIII. In humid regions millets are chiefly sown in early summer as catch crops, owing to the short period required for growth. In the northern plains district, where the growing season is too short for the sorghums, they are of increasing importance for grain production. Zavitz of the Ontario Agricultural College,[19] from 10-year plot tests with various types of foxtail millets, reports average yields per acre ranging from 33.8 to 49.3 bushels weighing 51 to 54.5 lbs. each. Hume and Champlin obtained an average of 16.4 bushels per acre with various types of proso millets in trials covering 6–7 years at the Highmore, South Dakota, Station,[20] and of 20.7 bushels for foxtail millets in trials during 6 years. Wilson and Skinner of the South Dakota Station[21] produced 30 bushels of hog, or Black Veronesh millet, *Panicum miliaceum,* per acre. The ground grain proved satisfactory for fattening swine, tho for a given gain one-fifth more millet was required than of wheat or barley. The carcasses of the millet-fed pigs were clothed with a pure white fat of superior quality. At the same Station[22] in the production of baby

[15] S. D. Bul. 135.
[16] Wis. Sta., Rpt. on Amber Cane, 1881.
[17] N. J. Rpt. 1885.
[18] Country Gentleman, March 23, 1876.
[19] Ont. Agr. Col. Rpt. 1913.
[20] S. D. Bul. 135.
[21] S. D. Bul. 83.
[22] S. D. Bul. 97.

beef somewhat more millet than corn was required for a given gain. (**744, 854, 952**)

III. Buckwheat and its By-products

Tho rarely used for feeding stock, buckwheat has a fair value for such purpose, its nutrients running somewhat lower than those in the leading cereals. (**953**)

244. Buckwheat by-products.—The black, woody hulls of the buckwheat grain, *Fagopyrum esculentum,* have little feeding value and should be used to give bulk or volume to the ration only when it cannot be otherwise secured. On the other hand, *buckwheat middlings,* that part of the kernel immediately under the hull, which is separated from the flour on milling, contain 28 per ct. crude protein and 7 per ct. fat, with little fiber, and hence have a high feeding value. The miller, desiring to dispose of as much of the hulls as possible, mixes them with the middlings to form *buckwheat bran* or *feed.* Woll[23] concludes that buckwheat feed, not over half of which is hulls, is worth about 20 per ct. less than wheat bran. Such feed carries about 15.7 per ct. protein and 24 per ct. fiber. The intelligent purchaser avoids the worthless hulls so far as he can, choosing instead the rich, floury middlings. Buckwheat by-products are nearly always used for feeding cows, rightly having the reputation of producing a large flow of milk, but may be successfully fed in limited quantities to other farm animals. (**595**) The charge that buckwheat by-products make a white, tallowy butter and pork of low quality fails if they are not given in excess. When stored in bulk, buckwheat by-products are liable to heat unless first mixed with some light feed, like wheat bran. (**953**)

IV. Oil-bearing Seeds and their By-products

The annual crop of cotton, *Gossypium hirsutum,* in the United States now amounts to over 14,000,000 bales of 500 lbs. each with not less than 7,000,000 tons of cotton seed as a by-product, since for each pound of fiber, or lint, there are 2 lbs. of seed. Previous to 1860 the seed of the cotton plant was largely wasted by the planters, who often allowed it to rot near the gin house, ignorant or careless of its worth, while meat and other animal products which might have been produced from it were purchased at high cost from northern farmers. The utilization of the cotton seed and its products as food for man and beast furnishes a striking example of what science is accomplishing for agriculture.

According to Burkett and Poe,[24] 1 ton of cotton seed yields approximately:

Linters, or short fiber	27 pounds
Hulls	841 pounds
Cake, or meal	732 pounds
Crude oil	280 pounds
Loss, etc	120 pounds
Total	2000 pounds

[23] Wis. Cir. 42.

[24] Cotton, its Cultivation, etc.

245. Cotton seed.—The cotton seed carries about 19 per ct. fat, or oil, and nearly 20 per ct. crude protein. Formerly much seed was fed in the South, especially to steers and dairy cattle. Now little is fed before the oil is extracted, both on account of the value of the oil and because cottonseed meal usually gives better results. Burns of the Texas Station[25] found that 205 lbs. of cotton seed fed with cottonseed hulls and kafir grain was not equal to 100 lbs. of cottonseed meal for fattening steers, while Bennett[26] at the Arkansas Station found 44 lbs. of meal and 59 lbs. of hulls fed with cowpea hay fully equal to 100 lbs. of seed for steers. Owing to the high oil content, cotton seed sometimes has an unduly laxative effect. (**752**) Connell and Carson of the Texas Station[27] report that boiled or roasted seed produced larger gains and was more palatable and less laxative, but owing to the cost of preparation the gains were more expensive. Wet, moldy cotton seed, or that which has heated, should never be fed. (**598**)

246. Cottonseed cake and meal.—At the oil mills the leathery hulls of the cotton seed, which are covered with short lint, are cut by machinery, and the oily kernels set free. These kernels are crushed, heated, placed between cloths, and subjected to hydraulic pressure to remove the oil. The residue is a hard, yellowish, board-like cake about 1 inch thick, 1 ft. wide, and 2 ft. long. For the trade in the eastern and central states the cake is generally ground to a fine meal, for the western trade it is often broken into pieces of pea or nut size for cattle and coarsely ground for sheep, while the export cake is commonly left whole. For feeding out of doors the broken cake is preferable to meal as it is not scattered by the wind. Unadulterated cottonseed meal of good quality should have a light yellow color and a sharp, nutty odor. A dark or dull color may be due to age, to adulteration with hulls, to overheating during the cooking process, or to fermentation—all of which impair its feeding value.[28]

Cottonseed meal is one of the richest of all feeds in protein and carries over 8 per ct. of fat. The protein and fiber content vary considerably, depending chiefly on how thoroly the hulls are removed from the meal. The value of fresh and wholesome meal depends on the percentage of protein it contains; manufacturers and feed control officials have therefore agreed on the following classification of products:

Choice cottonseed meal must be perfectly sound and sweet in odor, yellow, not brown or reddish, free from excess of lint, and must contain at least 41 per ct. of crude protein.

Prime cottonseed meal must be of sweet odor, reasonably bright in color, and must contain at least 38.6 per ct. of crude protein.

Good cottonseed meal must be of sweet odor, reasonably bright in color, and must contain at least 36 per ct. of crude protein.

Cottonseed feed is a mixture of cottonseed meal and cottonseed hulls, containing less than 36 per ct. crude protein.

Owing to its wide variation in composition, cottonseed meal should be purchased on guarantee whenever possible.

[25] Tex. Bul. 110. [26] Ark. Bul. 52. [27] Tex. Bul. 27. [28] Hills, Vt. Rpt. 1909.

247. Cottonseed feed.—On northern markets *cottonseed feed,* which may consist largely of hulls, is often sold for but a few dollars per ton less than choice cottonseed meal. By appearance alone it is impossible to distinguish good cottonseed meal from finely ground cottonseed feed. Cottonseed feed may be an entirely legitimate product, for it is impossible to separate thoroly the hulls of certain kinds of cotton seed from the kernels. However, such feed should be bought at a price corresponding to its crude-protein content.

In case of doubt as to purity, the following simple test will show the approximate amount of hulls present in cottonseed meal.[29]

Place a teaspoonful of the meal (do not use more) in a tumbler and pour over it from 1.5 to 2 ounces of hot water. Stir the mass till it is thoroly wet and all the particles are floating. Allow it to settle for 5 to 10 seconds and pour off the liquid. If there has settled out in this time a large amount of fine, brown sediment which is noticeably darker than the fine yellow meal and which keeps settling out on repeated treatments with hot water, the product is low grade. All meals contain small quantities of hulls and will show dark specks when thus tested, but the results are striking when pure meal is compared with cottonseed feed.

248. Cold-pressed cottonseed cake.—Cold-pressed cottonseed cake, or "caddo" cake, is produced by subjecting the entire uncrushed, unheated seed to great pressure. In the residual cake there is a larger proportion of hull to meal than in normal cake, with correspondingly lower feeding value. This product is usually sold in nut or pea size but is sometimes ground to a meal. The crude-protein content of cold-pressed cake is a reliable guide to its feeding value. (**598, 751**)

249. The poison of cotton seed.—Practical experience and trials at the experiment stations unite in showing that cotton seed or cottonseed cake or meal is not always a safe feed. After a period of about 100 days steers closely confined and heavily fed on meal often show a staggering gait, some become blind, and death frequently ends their distress. The Iowa Station[30] reports the death of 3 steers, and blindness in others when 2.5 lbs. of cottonseed meal was fed with a heavy allowance of corn-and-cob meal. Hunt of the Pennsylvania Station[31] cites the death of 2 calves out of 3, fed a ration of 1 lb. of cottonseed meal with 16 lbs. of skim milk. Emery of the North Carolina Station[32] states that 2 calves died following the use of 0.25 to 0.5 lb. of cottonseed meal daily with skim milk. Gips[33] reports the death of 3 out of 8 cattle from eating moldy cottonseed cake.

Cottonseed meal is often fatal to swine. Pigs getting as much as one-third of their concentrates in the form of cottonseed meal thrive at first, but after 5 or 6 weeks, sometimes earlier, they frequently show derangement and may die. Restricting the allowance of meal, keeping the animals on pasture, supplying succulent feeds, or souring the feed may help, but no uniformly successful method of feeding cottonseed meal to swine has yet been found.

[29] Vt. Bul. 101. [30] Iowa Bul. 66. [31] Penn. Bul. 17. [32] N. C. Bul. 109.
[33] Arch. Wis. u. Prakt. Thierheilk., 14, 1886, p. 74.

Numerous efforts have been made during the past 20 years to determine the cause of the poisonous effect of cottonseed meal. The harm has been variously ascribed to the lint, the oil, the high protein content, to a poisonous albumin or alkaloid, to cholin and betaine, to resin present in the meal, to decomposition products, and to salts of pyrophosphoric acid. Further work shows that the poisonous effects are not due to any of these causes. Withers of the North Carolina Station[34] has recently attributed the poisonous quality to some substance which withdraws iron from the hemoglobin of the blood, thereby diminishing its power of carrying oxygen, which results in death. (**88**) He has therefore tried the effect of adding to the food a soluble iron salt (iron sulfate, or copperas) as an antidote. In some trials in this country feeding copperas has seemed to prevent poisoning, but in other instances pigs have died even when fed copperas with the cottonseed meal.

250. Rational use of cottonseed meal and cake.—Cottonseed meal is one of the most valuable of feeds when rationally fed, often being the cheapest available source of protein, and thru it, of nitrogen for maintaining soil fertility. (**435**) The amounts which may be safely fed to each kind of stock are fully discussed in the respective chapters of Part III. The most extensive use of cottonseed meal is by dairymen, for comparatively heavy allowances may be fed to milch cows without harm. (**596**) Fed in large amount, cotton seed or cottonseed meal produces hard, tallowy butter, light in color and poor in flavor. A limited quantity has little effect on the butter and is even helpful with cows whose milk produces a soft butter.

For fattening steers and sheep cottonseed meal, in limited amount, is one of the most satisfactory of nitrogenous supplements. (**750, 855**) Great numbers of steers are fattened at the oil-mill factories, often on a ration of 6 to 8 lbs. of cottonseed meal with cottonseed hulls or corn silage for roughage. Harrington and Adriance at the Texas Station[35] found that cotton seed produced harder fat than corn, the kidney, caul, and body fat of steers fed cotton seed having melting points 4.1°, 3.2°, and 8.7° C. higher, respectively, than the corresponding fats of corn-fed steers. The effect was even more marked in the case of sheep. In restricted amounts, mixed preferably with bulky feed, cottonseed meal has been fed to horses and mules with entire success. (**490**) Altho cottonseed meal is especially poisonous to swine, some feeders, guided by experience, use it in small amounts and for short periods with little loss. (**974**) Calves are easily affected by its poisonous properties. (**681**)

Cottonseed meal having a dull color due to improper storage, and that from musty and fermented seed should never be used for feeding stock. Cottonseed meal does not have the beneficial laxative effect of linseed meal, but instead is somewhat constipating. Much more care must be used in feeding it than in using linseed meal, but when carefully fed in proper combination with other feeds as good results may be secured with

[34] N. C. Cir. 5; Jour. Biol. Chem. 14, 1913, pp. 53-58.

[35] Tex. Bul. 29.

horses, dairy cows, and fattening cattle and sheep as when linseed meal is employed. This most nutritious feed, the richest in fertilizing constituents of all our common feeding stuffs of plant origin, is often spread directly on the land as a fertilizer. Obviously, its full value can be realized only when the meal is first fed to animals and the resulting manure applied to the soil. (**436**) With increasing knowledge of the usefulness of this feed, it is to be hoped that instead of annually exporting one-fourth the cottonseed cake and meal produced to other countries, as is now done, all will be fed on American farms.

251. Cottonseed hulls.—Cottonseed hulls, which contain somewhat less digestible nutrients than oat straw, are extensively employed in the South as roughage for cattle feeding. The hulls are low in crude protein, of which but a small part is digestible. With only 0.3 lb. of digestible crude protein in 100 lbs. the hulls have the extraordinarily wide nutritive ratio of 1 : 122, the widest of any common feeding stuff. Obviously they should be used with feeds which are rich in protein. Fed with cottonseed meal to steers by Willson at the Tennessee Station,[36] cottonseed hulls produced somewhat lower gains than corn silage, 100 lbs. of hulls replacing 170 lbs. of corn silage. (**773**) Because of their low palatability and digestibility cottonseed hulls are not well suited to dairy cows, corn stover having a higher feeding value. (**628**)

Cottonseed hulls are usually fuzzy, due to short lint which remains on the seed. Sometimes this lint is removed from the seed at the oil-mills for paper making and other purposes and the hulls from such seed ground, being then called *cottonseed hull bran.* Tho finely ground, the value of the product is not appreciably greater than that of ordinary hulls.

252. Flax seed.—The average production in the United States of seed from the flax plant, *Linum usitatissimum,* from 1909 to 1914 was about 18,847,000 bushels of 56 lbs., over 95 per ct. of which was grown in Minnesota, the Dakotas, and Montana.[37] The reserve building material is stored in the flax seed largely as oil and pentosans, instead of as starch, which most seeds carry, no starch grains being found in well-matured flax seeds. On account of the high commercial value of the oil it contains, flax seed is rarely used for feeding stock other than calves. (**681, 683**)

The oil of the flax seed is either extracted by the "old process," thru crushing and pressure as in the production of cottonseed oil, or it is dissolved out of the crushed seed with naphtha, the residue in either case being variously termed *linseed oil meal, linseed meal,* or simply *oil meal.* Pure linseed meal should contain no screenings. In the United States nearly all the linseed oil meal is made by the old process.

According to Woll,[38] in the manufacture of new-process oil meal the crushed and heated seed is placed in large cylinders or percolators, and naphtha poured over the mass. On draining out at the bottom the naph-

[36] Tenn. Bul. 104. [37] U. S. Dept. Agr. Yearbook, 1914. [38] Wis. Rpt. 1895.

tha carries with it the dissolved oil. After repeated extractions steam is let into the percolator, and the naphtha remaining is completely driven off as vapor, leaving no odor of naphtha on the residue, which is known as "new-process" linseed oil meal. Woll gives the following method of ascertaining whether oil meal is new- or old-process: "Pulverize a small quantity of the meal and put a level tablespoonful of it into a tumbler; then add 10 tablespoonfuls of boiling hot water to the meal, stir thoroly, and leave to settle. If the meal is new-process, it will settle in the course of an hour and will leave half of the water clear on top." Old-process meal will remain jelly-like. Recent investigations have shown that in some instances flax seed may contain a compound which, when acted upon by an enzyme in the seeds yields the poison, prussic acid. This enzyme is destroyed by the heat to which the ground flax seed is ordinarily subjected in both the old and the new process of oil extraction. In view of this and bearing in mind that linseed meal and cake have been fed on vast numbers of farms in this country and abroad with the best of results, we may still consider these feeds among the safest and most beneficial of concentrates. In making gruel or mash from untreated flax seed, it is advisable to use boiling water and keep the mass hot an hour or two, to destroy any prussic-acid-forming enzyme in the seed.

253. Old- and new-process oil meal.—Since the oil is extracted much more thoroly from the flax seed by the new process, new-process meal carries an average of 3.0 per ct. more crude protein than old-process meal, but only about 2.9 per ct. of oil or fat. By artificial digestion trials with old- and new-process oil meal Woll[39] found that 94 per ct. of the crude protein in the old-process and 84 per ct. of that in the new-process oil meal was digestible. The lower digestibility of the new-process meal is doubtless due to the use of steam for driving off the naphtha, since cooking lowers the digestibility of many crude protein-rich foods. (**83**) Owing to its higher total crude-protein content the new-process meal, however, contains somewhat more digestible crude protein.

254. Linseed meal as a feed.—There is no more healthful feed for limited use with all farm animals than linseed oil cake or oil meal, with its rich store of crude protein, slightly laxative oil, and its mucilaginous, soothing properties. Its judicious use is soon apparent in the pliable skin, the sleek, oily coat, and the good handling quality of the flesh of animals receiving it. It is therefore most useful as a conditioner for run-down animals. A small amount of linseed meal is helpful in the rations for horses and dairy cows. (**489**) Opposite in effect to cottonseed meal, linseed meal tends to produce soft butter. (**599**) Fed to fattening cattle, sheep, or swine, the meal regulates the system and helps to ward off ill effects from the continued heavy use of concentrates. Rich in protein and all the necessary mineral elements, linseed meal is well suited to growing animals, ground flax seed or linseed meal being quite generally used for calves by progressive dairymen. Owing to its popularity linseed meal is often expensive compared with other protein-rich feeds and

[39]Wis. Rpt. 1895.

it is then not economical to employ it as the chief source of protein in the ration, but to restrict its use to amounts sufficient to produce the desired tonic and regulative effects. (**753, 855, 973**)

Unfortunately the American farmer usually insists that oil cake be ground to a meal. Except where it is desirable to mix the meal thoroly with other concentrates, or feed it as a slop to pigs, he should adopt the wiser practice of European farmers, who buy oil cake in slab form and reduce it in cake mills to the size of hickory nuts or smaller just before feeding, or he should purchase the cake which has been ground to nut or pea size. In such form this feed is more palatable, and there is no chance for adulteration.

255. Other flax by-products.—*Flax feed* consists of flax screenings and is sometimes sold as such, but more often is used as a component of mixed feeds. Its composition and character are uncertain, depending on the relative amounts of inferior flax seed, weed seeds, and other refuse, as stalks, pods, and leaves present. The material should be avoided unless so finely ground as to crush all foul seeds. Since it contains only half as much crude protein as linseed meal and often has a decidedly bitter taste, due to the weed seeds present, flax feed is rarely economical at the prices asked.[40] It is sometimes sold as flax flakes, or under the misleading name "linomeal."

Flax plant by-product, sometimes incorrectly called "flax bran," is that portion of the flax plant remaining after the seed has been separated, together with much of the fiber of the stem. It consists of flax pods, broken and immature flax seeds, and the bark and other portions of the stems. It is seldom sold as such, but is used in certain proprietary feeds. Smith of the Massachusetts Station[41] concludes that such material is not worth to the Massachusetts farmer the cost of the freight from the states where it is produced.

Unscreened flax oil-feed, or "laxo" cake meal, is the by-product obtained in extracting the oil from unscreened flax seed. The value is lower than that of linseed meal, depending on the proportion of screenings present.

256. Soybean.—The soybean, *Glycine hispida,* is one of the most important agricultural plants of northern China and Japan. So great is the production of this seed, or grain, in Manchuria that in 1908 over 1,500,000 tons of soybeans were shipped from 3 ports, chiefly to Europe. The bean-like seeds of the soybean, which carry from 16 to 21 per ct. of oil, are used for human food and for feeding animals. The oil is used for human food and in the arts, and the resulting *soybean meal* is employed as a feed for animals and also for fertilizing the land, the same as cottonseed meal. This plant produces the largest yield of seed of any legume suited to temperate climates, but at the present time is grown in this country chiefly for forage. Soybeans are adapted to the same range of climate as corn, early varieties having been developed that ripen seed wherever corn will mature. On account of their resistance to drought

[40] Mass. Buls. 128, 132; Vt. Buls. 104, 133, 144.

[41] Mass. Bul. 136.

they are especially well suited to light, sandy soils. When grown for seed the yield commonly varies from 12 to 40 bushels per acre, equaling corn on poor soil in the Gulf states.

The seeds of the soybean are the richest in crude protein of all the various seeds used for feed, besides being rich in oil. Being highly digestible, they contain fully as much digestible crude protein and considerably more digestible fat than linseed meal. Because of the demands for seed, soybeans have not yet been extensively employed in this country for feeding live stock. For dairy cows soybeans are slightly superior to cottonseed meal, but as they cause soft butter they should be fed sparingly. (**600**) For fattening cattle soybeans are only slightly inferior to cottonseed meal. (**754-5**) Rich in protein and mineral matter, they are well suited to growing animals, equal parts of soybeans and shelled corn proving superior for lambs to equal parts of oats and corn in a trial by Humphrey and Kleinheinz at the Wisconsin Station.[42] (**856**) Owing to their richness in protein, soybeans should always be used in combination with carbonaceous concentrates. The seed should be ground for horses and cattle, but this is unnecessary for sheep and pigs. In the South pigs are often grazed on soybeans when nearly mature, thus saving the harvesting cost. (**989**) The merits of this plant for forage are discussed in Chapter XIV. (**358**) No other plant so little grown in the United States at this time promises so much to agriculture as the soybean, which not only yields protein-rich seed and forage but builds up the nitrogen content of the soil.

257. Soybean cake or meal.—The residue after the oil has been extracted from soybeans carries as much digestible protein as choice cottonseed meal, 11 per ct. more carbohydrates and somewhat less fat. During recent years a considerable amount has been imported to the Pacific Coast states from the Orient, for feeding poultry and dairy cattle. In Europe the unground cake is used and in this country the meal. Tho high in price, soybean meal is greatly esteemed by western dairymen and is often fed in large amounts to cows on official tests. (**601**)

258. The peanut and its by-products.—The peanut, or earth nut, *Arachis hypogaea,* called "pindar" or "goober" in the South, is of growing importance for stock feeding in the southern states. The underground seeds, or nuts, are commonly harvested by turning swine into the fields when the seeds are ripe, and allowing them to feed at will. While a heavy allowance of peanuts produces soft fat and inferior pork, entirely satisfactory ham and bacon are produced when pigs are fed partially on peanuts. (**979**) On exposure to the air, shelled peanuts soon become rancid. The vines with the nuts attached may be gathered and cured into a nutritious, palatable hay useful with all kinds of farm stock. The use of this plant for stock feeding should be vastly extended thruout the South. (**362**)

Peanut meal or *cake,* the by-product resulting from the manufacture of oil from the peanut, is a common feed in Europe where it has given

[42] Wis. Rpt. 1905.

good results with all classes of stock.[43] Meal from hulled peanuts contains over 47 per ct. crude protein, and is thus more valuable than choice cottonseed meal. But little peanut meal is sold in the United States and that which is sold is chiefly from unhulled nuts, containing about 28 per ct. crude protein and 23 per ct. fiber.

Peanut hulls, which accumulate in great quantities at the factories, are sometimes ground and used for adulterating feeding stuffs. This material, sometimes wrongly called "peanut bran," is over half fiber and less valuable than common straw.

259. Sunflower seed and oil cake, *Helianthus annuus.*—The sunflower is grown in Russia on a commercial scale, one variety with small seeds producing an oil which serves as a substitute for other vegetable oils. The large seeds of another variety are consumed as a dainty by the people. Tests of sunflowers in 5 sections of North Carolina[44] showed an average yield of 65 bushels of seed per acre, carrying about 21 per ct. oil. In plot tests covering 15 years at the Ontario Agricultural College, Zavitz[45] obtained an average yield per acre of 72.8 bushels of sunflower seed, weighing 20 lbs. per bushel. Despite these large yields, corn produced about as much digestible crude protein and over twice as much total digestible nutrients per acre in grain alone, without considering the value of the stover. Sunflowers proved hardy and produced good returns when many other crops failed.

Oil cake from sunflower seed has proved a satisfactory feed for all kinds of stock in Europe. Cake from well-hulled seed contains about as much crude protein as linseed meal, but has somewhat more fiber. (**603**)

260. Cocoanut meal.—The residue in the manufacture of oil from the cocoanut, *Cocos nucifera,* known as *cocoanut meal,* is lower in crude protein than the oil meals previously discussed but it contains somewhat more crude protein than wheat bran and much more fat and has a higher feeding value. It is used to some extent by dairymen in the Pacific Coast states and produces butter of good quality and firmness, therefore being well adapted for summer feeding. (**602**) European experience shows that cocoanut meal may be fed with success to horses, sheep, and swine. (**491**) On account of its tendency to turn rancid it can be kept but a few weeks in warm weather.

V. Oil-free Leguminous Seeds

261. The Canada field pea, *Pisum sativum.*—The common field or Canada pea succeeds best where the spring and summer heat is moderate, as in Canada, the northern states, and in several of the larger Rocky Mountain valleys. No other widely known grain plant of equal possibilities has been so generally neglected by the farmers of the northern United States. Zavitz[46] of the Ontario Agricultural College reports an average

[43] Pott, Ernähr. u. Futter., III, 1909, pp. 82-96.
[44] N. C. Bul. 90b.
[45] Ont. Agr. Col. Rpt. 1913.
[46] Ont. Agr. Col. Rpt. 1913.

yield of 30 bushels per acre for 8 varieties of field peas in plot tests covering 14 years.

The field pea grain contains twice as much crude protein as the cereals and is high in phosphorus and potash. Combined with corn, peas may form as much as one-half the concentrates for dairy cows. They are relished by horses, and are eminently suitable for sheep and lamb feeding, their culture forming the basis for an important sheep-feeding industry in Colorado. (**856**) Peas, wheat bran, and corn form an excellent ration for brood sows and growing swine, proving especially useful in building the body framework and preparing the animals for fattening. (**975, 1013**)

262. Cowpea, *Vigna catjang.*—The cowpea, a bean-like plant from India and China, now holds an important place in southern agriculture because of its large yield of forage. The early varieties grow well as far north as New Jersey and Illinois. The seed pods of the cowpea ripen unevenly, necessitating hand gathering. For this reason the crop is mostly used for hay, silage, and grazing. (**357**) In composition the cowpea seed is similar to the field pea, with only about 4 per ct. fiber. Successful trials are reported in which cowpeas formed a part of the ration for horses, fattening steers, and pigs. (**755, 978**) In the South cowpea vines carrying ripe seed furnish one of the best grazing crops for pigs.

263. The common field bean, *Phaseolus vulgaris.*—Many varieties of the common field bean are grown in this country for human food. Beans damaged by wet are used for animal feeding. Shaw and Anderson of the Michigan Station[47] estimate the cull beans of Michigan at about 100,000 bushels annually. Cull beans are fed whole in large quantities to sheep, producing a solid flesh of good quality. For swine, beans should be cooked in salted water and fed in combination with corn, barley, etc.; fed alone they produce soft pork and lard with a low melting point. (**976**)

264. Horse bean, *Vicia faba.*—The horse bean is used in England for feeding stock, especially horses. This legume grows fairly well in some parts of Canada, but has never proved a success in the United States. (**485**)

[47] Mich. Bul. 243.

CHAPTER XI

MISCELLANEOUS CONCENTRATES—FEEDING STUFFS CONTROL—CONDIMENTAL FOODS

I. Cow's Milk and its By-products

As we have seen (**115**), milk contains an adequate supply of all the nutrients necessary to sustain the life of young animals. Milk and dairy by-products are almost wholly digestible and thus have high feeding value, considering the amount of dry matter they contain. Furthermore, the proteins of milk, which are well balanced in composition, have a greater efficiency for growth than those of any of the grains. (**118**)

265. Whole milk.—On account of the value of whole cow's milk, it is rarely fed to stock, except to calves for the first 4 to 6 weeks after birth. (**679**) One should not hesitate to employ whole milk when needed in rearing an orphan foal or lamb (**521, 891**), and young stock being prepared for exhibition can be forced ahead rapidly by its judicious use.

Whole milk usually contains from 2 to 3 per ct. of casein, 0.4 to 0.9 per ct. albumin and traces of other proteins. It carries from 4 to 5 per ct. of milk sugar, which is only slightly sweet, is much less soluble than cane sugar, and has about the same feeding value as starch. When milk sours, some of the sugar is changed to lactic acid, which curdles the casein. This fermentation ceases when about 0.8 per ct. of acid has developed, so that in sour milk usually most of the sugar is still unchanged. As is shown later (**551-5**), the percentage of fat varies widely depending on individuality, breed, and the portion of the milk drawn, the strippings often containing 10 times as much fat as the first-drawn milk.

266. Skim milk.—Because of the protein and ash it carries, skim milk is of high value for building the muscles and bony framework of young animals. Skim milk from centrifugal separators contains about 3.8 per ct. crude protein, 5.2 per ct. nitrogen-free extract, which in sweet milk is practically all milk sugar, and 0.1 to 0.2 per ct. fat. It is thus a highly nitrogenous feed, having a nutritive ratio of 1:1.5, and should hence be supplemented by carbonaceous concentrates. Skim milk is of the greatest use for feeding young animals when it comes sweet and yet warm from the farm separator.

The experiments of Beach, already described (**117**), show that with calves, lambs, and pigs, skim milk is more valuable per pound of dry matter than is whole milk rich in fat. Dairymen have found that with care and judgment they can raise just as thrifty calves when whole milk is gradually replaced by skim milk during the first 4 to 5 weeks, only skim milk being given thereafter, as when the supply of expensive whole milk is continued longer. (**678-94**) For swine of all ages, and especially for young pigs, skim milk is unsurpassed as a supplement to the carbonaceous grains. (**957-60**) For these animals, from 500 to 600 lbs. of skim milk, properly combined with concentrates, has a value equal to 100 lbs. of grain. This dairy by-product is also excellent for foals which do not secure enough milk from their mothers, and for poultry. (**521**) When other animals are not available to consume all the milk it may be profitably fed to horses. (**607**)

267. Buttermilk.—This by-product differs little from skim milk in composition, tho usually somewhat richer in fat. Trials have shown that it has substantially the same value as skim milk for pigs. (**962**) Some feeders use buttermilk successfully in rearing calves, especially after they are well started in growth. The effort will probably end in failure, however, unless the calves are gradually accustomed to it, and extreme cleanliness is practiced. (**695**) In eastern Prussia and in Holstein-Friesia suckling foals are fed buttermilk.[1] Creameries often dilute buttermilk with water, thereby reducing its value. If allowed to ferment in dirty tanks it is a dangerous feed.

268. Whey.—In the manufacture of cheese practically all the casein and most of the fat go into the cheese, leaving in the whey the milk sugar, the albumin, and a large part of the ash. Whey is more watery in composition than skim milk, containing only about 6.6 per ct. dry matter. It contains about 4.8 per ct. milk sugar and 0.3 per ct. fat, with only 0.8 per ct. protein, the nutritive ratio being 1 : 6.8, much wider than that of skim milk. Unlike skim milk and buttermilk, whey should therefore be fed with protein-rich feeds. Skimmed whey will have its value correspondingly reduced. Whey is usually fed to pigs, for which it has about half the value of skim milk. (**963**) At the Ontario Agricultural College,[2] Day secured as good results with whey, somewhat soured, as with sweet whey. The feeder should not conclude from this that decomposing whey held in filthy vessels is a suitable feed for stock. Whey at best is a poor feed for calves and can be successfully used only with the utmost care and when fed as fresh as possible. (**587**)

269. Spreading disease thru dairy by-products.—Since milk from different farms is mixed at the creamery and cheese factory, the germs of bovine tuberculosis and other diseases may be widely spread from a diseased herd in the skim milk, buttermilk, or whey. The readiness with which such infection may occur is shown by a trial of Kennedy, Robbins, and Bouska at the Iowa Station.[3] Forty pigs, believed to be free from tuberculosis, were divided into 4 lots. Two lots were kept on separate pastures and 2 in dry yards. Corn and creamery skim milk which had been pasteurized to destroy all disease germs were fed to all alike. The milk of one lot on pasture and one lot in the yard was, before feeding, infected with the germs of tuberculosis. When the pigs were slaughtered at the end of 196 days it was found that all that had been fed on infected

[1] Pott, Ernähr. u. Futter., III, 1909, p. 475.
[2] Ont. Agr. Col. Rpt. 1896.
[3] Iowa Bul. 92.

milk, 20 in number, were tuberculous. Of those not given infected milk, 2 proved tuberculous and 18 were free from the disease.

Since the germs of tuberculosis are killed by pasteurizing the milk at a temperature of 180° F., this simple precaution will remove danger from this source. The pasteurized product also keeps better and is less likely to produce scours. This practice is likewise advantageous to the factories, for the milk cans may be more readily kept in good condition and the quality of the milk delivered at the factory will thereby be improved. Careful farmers should insist that skim milk, buttermilk, and whey be thoroly pasteurized at the factory, a practice required by law in Denmark and followed by many creameries in this country. (**957**)

II. Packing House By-products

The packing houses now furnish to the feeder great quantities of by-products, including tankage, meat meal, or meat scrap, dried blood, and meat-and-bone meal. These are usually extremely rich in protein which is well balanced in composition and highly digestible. Most of them are also rich in lime and phosphoric acid, since they contain more or less bone. When fed in proper combination with other feeds, animals rarely object to these by-products. Owing to the high prices which these concentrated feeds command, the feeder should understand their nature and how they must be fed to secure the best returns.

270. Tankage, meat meal, or meat scrap.—At the packing plants the fresh meat scraps, fat trimmings, and scrap bones are thoroly cooked in steel tanks by steam under pressure, which separates the fat. After the steam has been turned off and the mass has settled, the fat, which is yet liquid, is drawn off. The residue is then dried, being agitated meanwhile, and after cooling is ground to a fine meal. The resultant product, sold as tankage, meat meal, or meat scrap, contains from 40 to 60 per ct. or more of crude protein and from 1 to 10 per ct. of fat. The variation in content of crude protein is due principally to differences in the amount of bone present. Owing to the wide range in crude protein, and fat content, these feeds should always be purchased on guarantee of composition. Commonly the value will depend on the percentage of protein, for in case an additional supply of lime and phosphoric acid is needed, it may be furnished cheaply in ground rock phosphate. (**100**)

Since tankage and meat meal are in part produced from the carcasses of diseased animals, the question arises whether they may not carry disease to animals fed on them. Mohler and Washburn,[4] who have studied the matter, write: "As tankage is thoroly steam-cooked under pressure it comes out a sterilized product, and owing to its dryness there is little danger of infection." None of the many stations that have fed tankage have reported any trouble of such nature. These by-products are generally fed to swine and poultry, ranking next to skim milk and buttermilk as nitrogenous supplements for these animals. (**964-7**) Mixed with other feeds,

[4] U. S. Dept. Agr., Bur. Anim. Indus., Cir. 144.

they may be fed to horses, cattle, or sheep. (**491, 608, 856**) When tankage, or meat meal, contains a large amount of bone it should be termed *meat-and-bone meal.* This product is used chiefly for feeding poultry.

271. Blood meal.—Blood meal, also called blood flour or dried blood, is the richest in protein of all the packing house by-products, usually carrying over 80 per ct. crude protein. As it contains no bone it is low in ash compared with tankage. Dried blood is particularly useful with young pigs and calves, as a skim milk substitute or for sickly animals. (**968, 684**) Its usual high price stands in the way of its common use for other animals. Lindsey[5] of the Massachusetts Station found that 1 to 2 lbs. of dried blood per head daily mixed with other concentrates was satisfactory for dairy cows. (**608**) It has also been fed with success to horses and sheep. (**491, 856**)

272. Dried fish; fish meal.—Along the coasts of Europe the waste parts of fish, as well as entire fishes not used for human food, are fed in dried form to animals. Speir of Scotland[6] reports no bad influence on milk when reasonable quantities of dried fish are fed to dairy cows. Nilson[7] found that 80 parts of herring cake could replace 100 parts of linseed cake for cows. The better grades of dried fish meal, which resemble meat meal in composition, should be used for feeding farm animals. (**608**)

273. Bone meal.—Where rations are deficient in lime and phosphoric acid, needed in especially large amounts by growing animals and those producing milk (**119, 150**), these mineral constituents may be supplied in the form of bone meal, also called ground bone. Ground rock phosphate is, however, usually a cheaper and probably just as effective a mineral supplement.

III. Sugar Factory By-products

In the manufacture of beet sugar, which constitutes over 70 per ct. of the sugar now manufactured in this country, the sugar beets are first washed and then cut into long V-shaped strips. The juice is extracted from these strips by means of warm water, leaving the by-product known as *wet beet pulp.* The juice is next purified by means of lime and in some cases also by sulfur dioxid, and evaporated under reduced pressure until the sugar crystallizes. The grains of sugar are then separated from the residual *molasses* by centrifugal force.

274. Wet beet pulp.—The watery pulp after being pressed until it contains about 10 per ct. of solids, is fed fresh or is ensiled. Care must be taken in feeding fresh pulp, as it spoils rapidly on exposure to the air. Most of the pulp is therefore fed as soured or ensiled pulp. When fed near the factories the pulp is dumped into large, shallow, well-drained pits or trenches, or into huge tank-like silos built chiefly above ground.

[5]Mass. Rpt. 1909, Part II, p. 157.

[6]Trans. Highl. and Agr. Soc., 1888, pp. 112–128.

[7]Kgl. Landtbr.-Akad. Handl., 1889, p. 257.

A more wasteful method is to pile the pulp in large heaps, when the outside layer on rotting will protect the interior from the air. On farms the pulp may be stored in ordinary silos or placed in pits, either with or without alternate layers of beet leaves, the mass, which may extend several feet above ground, being covered with straw and earth to keep out frost. Maercker[8] found that rather more than one-fourth of the total nutrients of the pulp was lost in the fermentations which take place when it is ensiled. Such heavy losses teach that, where possible, the pulp should be dried.

Tho carrying only 1 to 2 per ct. of sugar, wet beet pulp contains considerable of other easily digested carbohydrates, and per pound of dry matter is equal to roots in feeding value. Like roots, this watery material should be fed with dry feeds. Most of the mineral matter is extracted from the beets along with the sugar, and hence the pulp is low in these constituents. When heavy allowances of pulp are fed it is therefore well to see that the animals are supplied with sufficient lime and phosphoric acid. Pulp is also low in crude protein, but fortunately it is commonly fed with legume hay, which is high in both protein and mineral matter.

Steers are annually fattened by thousands and sheep by ten-thousands on wet, soured, beet pulp at the western beet-sugar factories. Carlyle and Griffith of the Colorado Station[9] found 1 ton of wet beet pulp equal to 220 lbs. of corn or 620 lbs. of alfalfa hay for fattening steers. (**746**) Griffin of the same station reports that 1 ton of pulp has about the same value as 200 lbs. of corn for fattening lambs. (**871**) The wet pulp is relished by dairy cows and, fed in not too large amount, produces a good flavored milk. (**643**) It may also be fed to idle horses. (**512**)

275. Dried beet pulp.—Owing to the high prices of concentrates and the favor with which dried beet pulp has been received by stockmen, many factories have been equipped with facilities for thus preserving the pulp. Shaw of the Michigan Station[10] found that dried beet pulp compared favorably with corn meal for fattening sheep and steers. It produced larger gains with growing animals, while corn meal put on more rapid gains with fattening animals nearing the finishing period. (**747, 854**) In the Scandinavian feed-unit system the value of dried beet pulp for dairy cows is rated 10 per ct. below corn or barley. (**585**)

As dried beet pulp absorbs a great deal of water, when a heavy allowance is fed it is advisable to moisten it with 2 to 3 times its weight of water before feeding.[11] Tho moistened dried beet pulp may be employed as a substitute for corn silage, at the usual prices the latter is the more economical form of succulence for those who can raise most of their own feed. Breeders of pure-bred dairy stock recommend dried beet pulp for cows on official test which are receiving heavy concentrate allowances,

[8] U. S. Dept. Agr., Bur. Chem., Bul. 52.
[9] Colo. Bul. 102. [10] Mich. Buls. 220, 247.
[11] Lindsey, Mass. Rpt. 1910, Part II, p. 24.

as it has a tendency to keep the bowels open and is not apt to cause digestive disturbances.[12]

276. Beet molasses.—The molasses from beet sugar factories is a valuable carbonaceous feed when properly fed, as it contains about 66 per ct. of nitrogen-free extract, which is nearly all sugar. The crude protein of both beet and cane molasses consists largely of compounds having little nutritive value.

When fed in too large amounts it is very laxative on account of its high content of alkaline salts and of other purgative substances. In the beet sugar districts the molasses is usually a cheap source of carbohydrates, its value per ton being rated at three-fourths that of corn. Due to its sticky nature, the molasses, either undiluted or thinned with water, is usually distributed over hay or straw, while large feeders use machines for mixing the molasses with cut roughage. Animals should gradually become accustomed to the molasses and care must be taken not to feed too large an allowance.

The maximum amounts of molasses advised by various authorities for animals accustomed to the feed are as follows, per 1,000 lbs. live weight: Driving horses, 2.5 lbs., and up to 4 lbs. or even more for draft horses; dairy cows, 2.5 to 3 lbs.; fattening cattle, 4 to 8 lbs.; fattening sheep, 3 to 5 lbs.; and fattening swine, 5 to 10 lbs. (**483, 748, 854**) Breeding animals should be given smaller allowances than those being fattened, and the amount should be materially reduced 6 weeks before delivery. Beet molasses is extensively used in various mixed feeds, described later. (**280**)

277. Molasses-beet pulp.—Beet molasses is sometimes combined with beet pulp and dried, forming dried molasses-beet pulp. This feed is somewhat more palatable and digestible than the ordinary dried pulp and has equal or slightly higher feeding value. (**586, 854**)

278. Beet tops.—At harvest an acre of sugar beets will usually yield about 4 tons of fresh leaves and 1 ton of the severed upper portion of the roots. The leaves have about half the feeding value of the roots. These tops, freed from soil as much as possible by shaking, may be fed fresh or ensiled. As fresh or ensiled leaves tend to purge the animals, they should always be fed in a limited way with such dried roughages as corn stover, straw, or hay. When large allowances of leaves are fed, Kellner advises giving about 3 ounces of chalk or ground limestone to every 100 lbs. of leaves, to counteract the effect of the oxalic acid which the leaves contain, and which may otherwise be injurious.[13] The tops may be ensiled in pits or silos in alternate layers with straw or may be mixed with cut dry corn fodder or stover. (**409**) German farmers add 7 lbs. of salt to each ton of leaves as they are ensiled.[14]

279. Cane molasses.—Cane molasses, or blackstrap, the by-product of the manufacture of cane sugar, is palatable and much relished by farm animals. When fed in large amounts it does not have the purgative

[12] Smith and Beals, Mass. Bul. 146.

[13] Ernähr. landw. Nutztiere, 1907, p. 307.

[14] Ware, Cattle Feeding with Sugar Beets, Sugar, and Molasses, etc.

effect of beet molasses, but tends to be costive in its action. It contains about the same amount of nitrogen-free extract as beet molasses. Tho the nitrogen-free extract of both cane and beet molasses is really all digestible, when molasses is fed with other feeding stuffs a depression of the digestibility of the basal ration occurs, as has been explained before (**84**), due to the large amount of soluble carbohydrates (sugars) it contains. Taking this into consideration, the digestibility of the nitrogen-free extract of cane molasses is reckoned at 90 per ct.

In the southern states cane molasses is often a cheap source of carbohydrates and is fed extensively on the sugar plantations to horses, mules, and other animals. (**482**) On account of the high price at which molasses is usually sold in the North, Lindsey of the Massachusetts Station concludes, after several years study, that no advantage is to be gained by northern farmers from the use of molasses in place of corn meal and similar feeds. For facilitating the disposal of unpalatable and inferior roughage, as a tonic for horses and cows out of condition, and as a colic preventive for horses (**482**), from 2 to 3 lbs. of molasses per head daily is helpful. He states that a daily allowance of 3 lbs. of molasses per head may be advantageously fed to fattening steers, especially during the finishing period, when the appetite is fickle. (**748**) Like beet molasses, blackstrap is commonly mixed with other feeds.

280. Molasses feeds.—Cane and beet molasses are now extensively used in the manufacture of the many *molasses feeds,* which consist of molasses combined with a wide range of products, all the way from high-protein concentrates, such as cottonseed meal, to milling offal, such as screenings, oat hulls, rice hulls, peanut hulls, etc. Many of the early molasses feeds contained a multitude of live weed seeds, were poor in mechanical condition, and did not keep well on account of excessive moisture. Often entirely unwarranted statements were made in advertising these feeds. The conditions have now improved, and where screenings are present they usually have been finely ground to destroy all weed seeds. Because of the widely differing materials used in these feeds their value varies greatly. If sold at prices which are reasonable compared with the cost of equal amounts of nutriment in the straight concentrates, nothing can be said against the use of the reliable feeds of this class, for they are well liked by stock. (**483**) However, deception is easy in these feeds, because the molasses masks the other ingredients so that inspection does not always show of what the feed consists. Molasses feeds should hence be purchased only from reliable dealers and on definite guarantees of composition and of freedom from live weed seeds. The state feed-control officials should be consulted in case of doubt as to the value of any molasses feed.

Molassine meal, which has been manufactured for several years in Europe and has recently come upon the markets in the United States, consists of molasses absorbed by sphagnum moss or peat. Kellner and Pfeiffer have shown[15] that peat has no nutritive value for farm animals,

[15]Kellner, Ernähr. landw. Nutztiere, 1907, p. 369.

and the undecomposed moss can likewise have but small worth, tho arctic life subsists on it to some extent. Practically the only nutriment in this feed is in the molasses it contains, and at the prices usually asked, molasses can be purchased much cheaper alone than in molassine meal. Hills[16] found the molasses in a ton of this meal worth only $25, while the feed sold for $39 per ton. Lindsey and Smith[17] of the Massachusetts Station found molassine meal decidedly inferior to corn meal for cows.

281. Sugar.—Tho the nutritive value of sugar is no greater than that of an equal weight of starch, the great fondness for it shown by farm animals makes it helpful in some cases for stimulating the appetite. (**484**) A small allowance is often used in fitting animals for shows. Owing to heavy internal taxes laid upon sugar for human consumption in France and Germany, it is sometimes denatured by mixing with it vermouth powder, lamp black, salt, peat, etc., after which it is used for feeding to animals.

282. Dried distillers' grains.—In the manufacture of alcohol and distilled liquors from cereals, the corn, rye, etc., after being ground, are treated with a solution of malt to convert the starch into sugar, which is next converted into alcohol by the action of yeast. This is distilled off, leaving a watery residue, known as *distillers' slops,* or *slump.* Formerly the slump was fed to fattening steers at the distillery; now the solid matter is usually strained out and dried in vacuum, forming *dried distillers' grains,* or *distillers' dried grains,* which are sold as such or under various proprietary names. This by-product consists of the portions of the grains not acted upon during the fermentation process, i.e., the crude protein, fiber, fat, and the more insoluble part of the nitrogen-free extract. Distillers' grains from corn contain from 28 to 32 per ct. crude protein and are about equal to gluten feed in feeding value. Dried grains chiefly from rye are of considerably lower value, carrying only about 23 per ct. protein. Not being especially palatable, distillers' grains should be mixed with other concentrates. This rather bulky feed is one of the best high-protein concentrates for dairy cows, from 2 to 4 lbs. per head daily being usually fed. (**605**) Distillers' grains may also be used with good results as part of the ration for fattening steers and sheep. (**758, 856**) A large allowance of the grains is usually not relished by horses, but they may constitute one-fourth the concentrate allowance for these animals. (**491**) On account of their bulkiness they should not be fed in large amounts to pigs. (**981**)

283. Acorns.—In some portions of the South and in California, acorns, the fruit, or nut, of the oak, *Quercus* spp., are of importance in swine feeding, the pigs usually being allowed to forage upon the scattered nuts. Carver of the Tuskegee, Alabama, Station[18] reports the successful feeding of acorns and kitchen slop to 400 pigs, allowing about 5 lbs. of acorns to each pig daily. Carver states that acorns produced a soft, spongy flesh and an oily lard, but this was doubtless due fully as much to the

[16] Vt. Bul. 171. [17] Mass. Bul. 158. [18] Ala. (Tuskegee) Bul. 1.

slop fed, as German investigators report that acorns produce pork of good quality. Acorns may be used in limited amounts for other stock. Cases of poisoning have been reported where animals ate damaged acorns or consumed an undue amount.

284. Cocoa shells.—This by-product of the manufacture of cocoa and chocolate consists of the hard outside coating, or bran, of the cocoa bean. These shells, which are dark brown and brittle, are used in a few proprietary feeds. Only 4 to 18 per ct. of the crude protein in this material is digestible. According to Kellner[19] cocoa shells have no more feeding value than straw. Lindsey and Smith found a lot tested at the Massachusetts Station[20] somewhat more digestible, but do not consider the shells worth more than half as much as corn meal.

285. Proprietary and mixed feeds.—There are now on the market a host of mixed feeds, chiefly sold under proprietary names. Widely different ingredients enter into the composition of these articles. In some only such high-grade concentrates as cottonseed meal, wheat bran, malt sprouts, gluten feed, dried distillers' grains, etc., are combined. Others contain varying amounts of screenings, or light grains of wheat, barley, or oats, which will in general have a lower value than good quality grain from the same cereals. The larger number contain more or less of such low-grade by-products as oat hulls, ground corn cobs, flax plant by-product, etc. Several states now require that the ingredients in any feed be stated on the sack or package. Tho the manufacturers of most of these feeds maintain the amount of crude protein, fat, and fiber in each brand at about the same figures from month to month, but few guarantee the amount of the separate ingredients, such as malt sprouts, or screenings, that the feed contains. Owing to this inability to know that a sample of the feed secured today will represent the feed put on the market next year under the same name, the experiment stations have conducted practically no trials to determine the values of these mixtures. For this reason and because of the great number of these feeds, the composition of proprietary mixed feeds is not shown in Appendix Tables I and III.

Many mixed feeds are the result of honest and intelligent effort to furnish a ready-mixed "balanced" concentrate mixture for dairy cows, horses, or cattle, as the case may be, and have won good reputations among intelligent feeders. Others are merely attempts to delude the purchaser into paying as high a price for a feed bearing a "fancy" name but consisting largely of low-grade materials as he would pay for high-class concentrates. Mixed feeds should therefore be purchased only when they are the product of reliable manufacturers, and especial attention should be paid to the guarantee of crude protein, fat, and fiber. On comparing the fiber guarantee with the fiber content of well-known unmixed concentrates, as given in Appendix Table I, the purchaser will be able to judge to what extent such low-grade by-products as oat hulls

[19] Ernähr. landw. Nutztiere, 1907, p. 214. [20] Mass. Bul. 158.

and corn cobs have been added. As has been pointed out (**203, 224**), such bulky materials, high in fiber, furnish but little nutriment, tho they may be helpful in adding bulk to the mixture. Before buying, the wise feeder will compare the amount of nutrients he can secure for a given sum in different mixed feeds and in the unmixed standard by-products.

IV. Commercial Feeding Stuffs Control

As has been pointed out in the previous chapters, it is often impossible for the feeder to tell from the appearance of a commercial feeding stuff whether it is of standard quality or has been adulterated. The enactment of laws has therefore been necessary to protect honest manufacturers and dealers, as well as the users of commercial feeds.

286. Regulation of sale of commercial feeding stuffs.—Laws have now been passed in a large number of the states which in general require that each package of concentrated feed bear a label, tag, or statement giving the percentages of crude protein and fat the feed contains. An increasing number of states are wisely requiring that the maximum percentage of fiber be also guaranteed. In others, each ingredient in all mixed feeds must be stated. From time to time the officials entrusted with feed supervision issue bulletins setting forth the results of examinations, analyses, etc. Those interested should consult the bulletins, and aid and support the officers in the administration of the laws.

Users of purchased feeds in large quantity are generally experienced and buy only the better grades of standard feeding stuffs at close prices, or secure such materials as screenings, etc., at low prices, fully understanding their composition and relative value. The small buyer, often feeling the pinch of poverty, too frequently is looking for something that sells for less than is demanded for standard goods, and so is the more easily caught by the low-grade, trashy articles often bearing catchy, high-sounding names. Low-grade feeding stuffs, no matter what their names, are almost sure to bring hardship to the animals that are fed on them, and to the owners of such animals as well. Such feeds are really more like roughages than concentrates and roughage can be produced on most farms far more economically than it can be purchased in bags from the feed dealer. Whenever one is in doubt as to what to buy, he should consult the feed control officials of his state or purchase only the pure unmixed grains, straight milling or factory by-products, or proprietary feeds of high grade that have won a good reputation.

287. Examples of feed adulteration.—Since the feed-control work has been carried on the instances of adulterated and misbranded feeds are becoming less frequent. The following will illustrate the fraud sometimes still attempted by unscrupulous manufacturers and dealers. In Tennessee the United States Department of Agriculture[21] seized a shipment labeled "Mixed Wheat Middlings, from Pure Wheat Bran and

[21] Notices of Judgment, 66, 67—Food and Drugs Act.

Ground Corn," which consisted of bran and ground corn cobs. Woll and Olson of the Wisconsin Station,[22] examining a carload of so-called wheat bran shipped into Wisconsin, found that each pound of the whole carload contained on an average 28,000 pigeon-grass seeds, 16,000 wild buckwheat seeds, 5,000 pigweed seeds, and many seeds of other kinds. Beach of the Vermont Station,[23] examining 18 brands of molasses and flax feeds offered for sale in his state, found from 1,150 to 131,000 weed seeds in each pound of such feeds. In one case it was estimated that there were 129 million weed seeds, weighing 400 lbs., in a ton of one of these feeds. Beach found that 2 to 13 per ct. of these seeds would grow after having passed thru the cow.

288. A guide in purchasing commercial feeds.—In purchasing commercial feeding stuffs the guaranteed composition should be ascertained and compared with the average composition given for the same feed in Appendix Table I. If the feed is markedly lower in crude protein or fat, or is noticeably higher in crude fiber than there shown, it should be viewed with suspicion. Care should also be taken that the feed is fresh, free from mold and rancidity, and that it corresponds in appearance with the descriptions given in the preceding chapters.

V. Condimental or Stock Foods

Proprietary articles styled "stock foods," "seed meals," "condition powders," etc., costing from 10 to 30 cents or more per pound, are extensively advertised and sold to American farmers. Woll of the Wisconsin Station,[24] after ascertaining the amount of stock foods sold in 1906 in three counties in Wisconsin, estimated that the farmers of that state paid annually about $300,000 for 1,500 tons of such material. Michel and Buckman of the Iowa Station[25] estimate that Iowa farmers paid $190,000 for stock foods in 1904.

289. Composition of stock foods.—The better class of stock foods have for their basis such substances as linseed meal or wheat middlings, while the cheaper ones contain ground screenings, low-grade milling offal, the ground bark of trees, etc. To this "filling" is added a small percentage of such materials as common salt, charcoal, copperas, fenugreek, gentian, pepper, epsom salts, etc., with or without turmeric, iron oxid, etc., for coloring. The stockman is told that a tablespoonful of the compound with each feed will cause his stock to grow faster, fatten quicker, give richer milk, etc., etc. Yet this amount will supply only an insignificant part of the dose of these drugs which is prescribed for animals by competent veterinarians. Tests of many of these stock foods by the experiment stations support the view of Sir John Lawes, the world's greatest investigator in scientific and practical agriculture, who, after carefully testing the stock foods then being sold in England wrote:[26] "In con-

[22]Wis. Bul. 97. [23]Vt. Buls. 131, 133, 138. [24]Wis. Bul. 151. [25]Iowa Bul. 87.
[26]Rothamsted Memoirs, Vol. II.

clusion, I feel bound to say that I require much clearer evidence than any that has hitherto been adduced, to satisfy me that the balance-sheet of my farm would present a more satisfactory result at the end of the year, were I to give each horse, ox, sheep, and pig, a daily allowance of one of these costly foods." (**928**)

Farm animals managed with reasonable care have appetites which do not need stimulating. Sick animals or those out of condition should receive specific treatment rather than be given some cure-all. A good manager of live stock has no use for high-priced stock foods or condition powders, and a poor manager will never have fine stock by employing them. In rare cases the available feeding stuffs may be of such poor quality that some condiment may cause the animal to eat more heartily, and where animals are in low condition and without appetite some spice may prove helpful. To cover such rare cases the formulæ for three "stock foods" or "spices" are presented.

First formula	Lbs.	Second formula	Lbs.	Third formula	Lbs.
Fenugreek	2	Powdered gentian	8	Ground gentian	4
Allspice	2	Ginger	8	Powdered saltpeter	1
Gentian	4	Fenugreek	8	Ground ginger	1
Salt	5	Powdered sulfur	8	Powdered copperas	1
Saltpeter	5	Potassium nitrate	8		
Epsom salts	10	Resin	8		
Linseed meal	100	Cayenne pepper	4		
		Linseed meal	44		
		Powdered charcoal	20		
		Common salt	20		
		Wheat bran	100		

The above materials are easily obtainable and there is no difficulty in compounding them. Oil meal or middlings is not necessary if one will thoroly mix together the other ingredients and give the proper amount along with some rich concentrate, like oil meal, wheat middlings, or ground oats. At ordinary prices for the materials, either the first or second formula can be made up for about 5 cents per pound, or about one-fourth what is usually charged for something no better. A tablespoonful in each feed will supply more drugs of possible value than the same measure of most of the advertised stock foods. The third formula, which is more concentrated, may be given at the rate of 1 tablespoonful daily mixed with the feed for 10 days, the dose omitted for 3 days, and then the tonic given for 10 days more. The flattering testimonials which the stock-food companies advertise are explained without granting any special virtue to their "food." The stock foods are usually accompanied by directions which advocate liberal feeding and good care for the animals to be fed in order to "secure the benefits from the tonic." Under this guidance the farmer feeds and cares for his stock better than ever before and secures better results, due not to the stock food but to following the directions which accompanied it. Rather than purchase advice with costly condimental foods the wise feeder will secure it in standard agricultural papers and books, or from the experiment stations and the United States Department of Agriculture.

CHAPTER XII

INDIAN CORN AND THE SORGHUMS FOR FORAGE

I. Indian Corn

Indian corn, maize, is the imperial agricultural plant of America. This giant annual grass reaches a height of from 7 to 15 feet in 4 or 5 months' growth, producing under favorable conditions from 10 to 25 tons of green forage per acre, containing from 4,000 to 10,000 lbs. of dry matter. When grown in a dense mass but little seed forms, and we have a rank grass which cures into a bright, nutritious, coarse hay. If the plants grow some distance apart, a large yield of grain results, with excellent forage as a secondary product.

Were a seedsman to advertise Indian corn by a new name, recounting its actual merits while ingeniously concealing its identity, either his claims would be discredited or he would have an unlimited demand for the seed of this supposed novelty. The possibilities of American farms in the live stock they may carry and the animal products they may turn off are restricted only by the quantity of corn and of clover or other legumes which the land will produce, and this, under good management, seems almost unlimited.

In Chapter I the studies on the composition of the growing Indian corn plant are given at length to illustrate and fix in mind the manner in which plants grow and elaborate food for animals. The student should turn to that most helpful presentation and carefully review what it teaches. This done he is in position to proceed with the further study of the maize plant here set forth. (The importance of corn as a cereal has already been discussed in Chapter IX.)

290. Corn as a forage plant.—The entire fresh green corn plant may be fed as a soiling crop, it may be ensiled, the crop may be cut and cured as fodder corn, or the grain may be removed and the remaining stover used for feed. As later shown (300), ensiling is by far the most satisfactory means of preserving the entire crop as forage.

The term *fodder corn* or *corn fodder* is applied to stalks of corn, green or dry, which have been grown primarily for forage, and from which the ears or "nubbins," if they carry any, have not been removed. *Shock corn* and *bundle corn* are terms applied to fodder corn which carries much grain, but which is fed without husking. *Stover* or *corn stover* denotes the dried stalks of corn from which the ears have been removed. Fodder corn or corn fodder, then, is the fresh or cured corn plant which has been grown for forage, with all the ears, if any, originally produced. Stover is cured shock corn minus the ears. Similarly, the terms kafir fodder, kafir stover, etc., are employed in speaking of sorghum forage.

291. Thickness of planting.—In a study of thick and thin seeding for 3 seasons at the Illinois Station,[1] Morrow and Hunt secured the results summarized below. In these trials the kernels were planted from 3 to 24 inches apart in the row, all rows being 3 feet 8 inches apart.

Results of planting corn kernels various distances apart in rows

Thickness of planting		Yield per acre		Digestible substance per acre			Stover per acre	Stover for each lb. of corn
Distance between kernels in row	Kernels per acre	Good ears	Poor ears	Stover	Grain	Total		
		Bu.	Bu.	Lbs.	Lbs.	Lbs.	Tons	Lbs.
3 inches........	47,520	13	46	3,968	2,250	6,218	4.8	3.6
6 inches........	23,760	37	39	3,058	2,922	5,980	3.7	1 9
9 inches........	15,840	55	22	2,562	2,977	5,539	3.1	1.5
12 inches........	11,880	73	16	2,480	3,113	5,593	3.0	1.3
15 inches........	9,504	63	11	2,398	2,782	5,180	2.9	1.4
24 inches........	5,940	49	6	2,066	2,141	4,207	2.5	1.5

With the kernels but 3 inches apart in the row there were 46 bushels of ''nubbins,'' or poor ears, and only 13 bushels of sound ears per acre. However, this thick planting gave the largest returns in digestible nutrients—over 6,000 lbs. per acre. With this close planting there were 3.6 lbs. of stover for each pound of grain. The largest yield of sound ear corn was secured by planting the kernels 12 inches apart in the row, or about 12,000 kernels per acre, which should produce 10,000 good stalks an acre. From this the returns were 73 bushels of sound and 16 bushels of poor ears per acre, with only 600 lbs. less digestible matter than from planting the kernels 4 times as thick. These trials, confirmed by the work of other stations, teach that when the stockman is seeking the greatest amount of nutrients possible from the corn crop he will plant the seed so thickly as to choke the ears to about half their natural size. If he aims to produce grain, with stover secondary, he will plant the kernels at such distance apart as will allow each individual plant to produce full-sized ears. No general rule can be given as to the amount of seed to be planted per acre. This varies greatly and is determined by local conditions. One must know accurately the capacity of his land for corn, and seed accordingly, bearing in mind that thick seeding gives the most total nutrients, largely as roughage, while thinner seeding gives the most sound grain.

292. Nutrients in the corn crop.—Even when grown for the grain, the stover contains a considerable part of the total nutrients of the crop, as is shown by the following table, arranged from a summary by Armsby[2] of trials at 4 northern stations.

[1]Ill. Bul. 13. [2]Penn. Rpt. 1887.

Distribution of nutrients in the corn crop grown for grain

	Average yield per acre	Distribution of digestible nutrients		Distribution of net nutrients
		Crude protein	Total digestible nutrients	
	Lbs.	Per ct.	Per ct.	Per ct.
Ears	4,415	75	63	76
Stover	3,838	25	37	24

The table shows that in the northern states somewhat more than half the total weight of the corn crop grown for grain is found in the ears. About 75 per ct. of the digestible crude protein is in the ears and 25 per ct. in the stover. The ears furnish about 63 and the stover 37 per ct. of the total digestible nutrients. For animals at light work, those fattening slowly or giving only a small quantity of milk, and for maintaining animals in winter when much heat for warming the body is required, the value of the stover will be approximately measured by the total digestible nutrients it contains, or 37 per ct. of the crop. For fattening animals and those giving much milk or at hard work the stover will have a lower value, on account of the large amount of fiber it contains. For such animals a more accurate measure of the relative value of the ears and stover is furnished by the last column, which shows that the ears supply 76 and the stover 24 per ct. of the net nutrients. (**78-80**) The ratio of grain to stalk, and hence the distribution of the nutrients, will vary with the variety and with the section of the country. The rank growing southern corn will have less of the total nutrients in the ear and more in the stalks. These data show clearly the great loss of animal food which occurs each year when unnumbered acres of stover are allowed to decay in the fields.

Like the corn grain, corn forage is low in crude protein compared with its carbohydrate and fat content. As shown in Appendix Table III the nutritive ratio of corn silage is 1:15.1, and that of fodder corn 1:15.7 to 1:17.1, while corn stover has the extremely wide nutritive ratio of 1:21.0 or over. Hence these roughages should be supplemented by feeds rich in crude protein. Corn forage is fair in phosphorus and high in lime, compared with corn and the other cereal grains.

293. Preserving corn fodder or stover.—Losses of nutrients in corn fodder after it has been gathered into shocks (stooks) are known to occur thru weathering but there are also large losses which are unexplained. During 4 years' study at the Wisconsin Station, Woll[3] determined the dry matter and crude protein in a crop of corn at the time of cutting and again after the shocks had been exposed to the weather for several months. It was found that under Wisconsin conditions well-made shocks of corn which stand in the field for a few months lose about 24 per ct. of their dry matter, the crude protein content suffering to the same extent. Cooke showed that in the dry climate of Colorado[4] heavy losses likewise occur in shock corn. In the South the corn forage,

[3] A Book on Silage. [4] Colo. Bul. 30.

maturing early, melts away to almost nothing in a comparatively short time. The substances first lost thru such wasting are crude protein, sugar, starch, etc.—the most valuable portions of the plant. Nor is it possible to entirely prevent these losses by placing the cured fodder under cover or in stacks. Losses of this nature are probably due to fermentations which slowly but steadily waste the substance of the forage. Sanborn[5] writes: "Many trials with fodder...make it certain that 15 per ct. is the minimum loss to be expected with dry storage, while the loss may rise to 20 per ct. or even more in ordinary practice."

The losses due to weathering can be lessened by making large shocks. Since the stalks stand almost vertical in the shocks, as the leaves wilt there is ample room for the upward passage of air currents, which rapidly dry the interior and check molds and fermentations. When shock corn is pronounced dry by the farmer, it often still carries more water and consequently less dry matter than hay, a fact which should not be overlooked when feeding this forage. Care must be taken that corn fodder or stover is well-cured before it is stacked, and especially before it is stored in the mow, for musty, moldy forage is not only unpalatable but even dangerous. In southern states where it is exceedingly difficult to cure corn stalks so that they may be stacked, the silo is particularly useful.

294. Dry fodder corn.—Corn grown and cured as forage constitutes a coarse hay of high feeding value, since only a portion of the nutrients has gone into the ear. Dry fodder corn is more palatable and nutritious than stover, which has transmitted much of its substance to the grain. Thickly seeded corn bears small, palatable ears which are easily masticated. When grown for coarse hay and carrying some grain, corn possesses a feeding value not as yet appreciated by most stockmen. Overlooking its splendid qualities as a hay plant, we have become accustomed to growing this grass for the grain it yields, and using the stover as a sort of straw to be eaten or wasted as accident determines. **(500, 620-1, 771, 862)**

295. Shock corn.—Rather than husk corn and feed the grain and stover separately, it is often more profitable to feed shock corn and allow the animals to do their own husking. This is especially true for animals which need only a small grain allowance, such as cattle being carried thru the winter or idle horses. Shock corn may also be successfully fed to fattening cattle and sheep, particularly at the beginning of the fattening period, and to a less extent it may be employed with the dairy cow. It is true that when fed unhusked some corn passes thru the animal unbroken, but feeding trials show that, despite such waste, there is often little or no profit in husking the ear and reducing it to meal. A little study will determine the amount of grain the shocks carry, so that the feeder can properly adjust the ratio of grain to rough-

[5] Cyc. Am. Agr., Vol. II, p. 569.

age by supplying either ear corn or corn stover as the animals may require. (**735, 771**)

296. Corn stover.—The forage which remains after removing the ears from shock corn has a higher feeding value than is usually conceded. Stover produced in the northern portion of the corn belt is superior in nutriment and palatability to that grown in the South. As soon as fairly well cured and freed from external moisture stover should be placed under cover or stacked, rather than left to deteriorate in the field. Waters of the Missouri Station[6] found as the average of experiments covering 4 years that moderately thin yearling steers lost only 33 lbs. each when wintered on corn stover alone. This shows that corn stover fed long or uncut will nearly furnish a maintenance ration for such animals. (**502, 622, 771, 862**)

297. Shredded or cut stover and fodder.—When shock corn is husked by machinery the stover is usually cut or shredded at the same operation. Corn fodder is also often passed thru a feed cutter before feeding. At the Wisconsin Station[7] the senior author conducted 3 trials in which cows were fed either shredded or unshredded corn stover or fodder corn, all receiving the same allowance of grain and hay. While on the average 18 per ct. of the long forage was refused, the shredded fodder was all consumed. In these trials 100 lbs. of shredded stover or fodder produced slightly more milk than 132 lbs. of long forage. At the Kansas Station[8] Shelton, in experiments covering 3 seasons, fed stover cut into lengths varying from 0.25 to 2 inches to cows, and found an average waste of 31 per ct. of the cut stover, with no greater milk returns than from the uncut stover. The finer the stover was cut the larger was the waste, and the conclusion was that the only advantage from cutting stover lay in the greater convenience of handling it in the stable. Likewise at the Missouri Station[9] Waters found shredded stover slightly inferior to whole stover for steer feeding. In accounting for these differences it may be said that the stalks of corn grown in the middle and lower portions of the corn belt are larger, coarser, more woody, and doubtless less nutritious than the smaller, softer stalks of the northern states. It is also possible that in the Kansas trial the sharp edges of the cut stalks made the mouths of the cattle sore. This can be avoided by changing the length of the cut or by shredding. Cutting or shredding corn forage makes it easier to handle, and the waste is in better shape for bedding and manure. As this finer material is not more digestible than long stover, the only other possible advantage comes in getting the animals to eat more, or to eat those parts which would otherwise be wasted.

298. Pulling fodder.—In the South the tops of the ripening corn stalks are quite commonly cut off just above the ears, leaving the tall butts, each with an unhusked ear at its top. Next, the leaves are stripped from the butts, and these together with the severed tops are cured into a

[6] Mo. Bul. 75. [7] Wis. Rpt. 1886. [8] Kan. Rpt. 1889. [9] Mo. Bul. 75.

nutritious, palatable fodder, which is extensively employed for feeding horses and other stock. The previous study of the development of the nutrients in the corn plant shows the folly of this practice. During the last stages of its life the corn plant is busiest in gathering crude materials from air and soil and elaborating them into nutritious food. Removing the top and leaves, at once stops all this work of food making. Stubbs of the Louisiana Station[10] found that pulling fodder caused a shrinkage of from 15 to 20 per ct. in the yield of grain. (23)

299. The new corn product.—The pith of the cured corn stalk is used as a packing between the walls of vessels to prevent the entrance of water should the hull be pierced, as well as being employed in various industries. It has been found that for each pound of pith there are 15 lbs. of blades, husks, and parts of stalks which remain as a by-product. This waste, ground to a powder, has been named "the new corn product." At the Maryland Station[11] Patterson found the new corn product somewhat more digestible than whole stover in feeding trials with steers and equal to hay for horses.

As this material is used as a filler in some mixed feeds, it is well to bear in mind that grinding the by-product does not increase its content of nutrients.

300. Indian corn for silage.—Indian corn is pre-eminently a silage plant. The solid, succulent stems and broad leaves, when cut into short lengths, pack closely and form a solid mass which not only keeps well but furnishes a product that is greatly relished by stock, and consumed with little waste. Altho with enlarging experience the use of other crops for silage is increasing rapidly, by far the greater portion of all the forage stored in silos in this country is corn. The importance of silage on American farms is discussed further in Chapter XVI and in the respective chapters of Part III.

301. Losses by ensiling and field-curing.—After studying the losses of forage preserved in wooden silos during 4 seasons at the Wisconsin Station,[12] King concludes that, omitting the top and bottom waste, which is the same for deep or shallow silos, the losses of dry matter in corn silage need not exceed 10 per ct. Considerable of the protein in ensiled fodder is changed to amids (11), and some of the starch and sugar is destroyed, while the fiber is not diminished; thus the losses fall on the best portions of the ensiled material. Numerous trials at the stations show practically no difference between the digestibility of corn silage and dry corn fodder, but both are somewhat less digestible than the green forage. This is shown in the average digestion coefficients given in Appendix Table II.

The following table summarizes the comparative losses in preserving corn forage by ensiling and field-curing as shown by 10 trials at 4 stations:

[10] La. Bul. 22. (Old Series.) [11] Md. Buls. 43, 51. [12] Wis. Bul. 59.

Relative losses of field-curing and ensiling the corn crop

Station and reference	Corn silage Dry matter Per ct.	Corn silage Crude protein Per ct.	Corn fodder in shocks Dry matter Per ct.	Corn fodder in shocks Crude protein Per ct.
Vermont, av. 4 yrs., Rpts. 1889–94	18.2	12.0*	17.7	12.7*
New Jersey, Bul. 19	18.0	....	17.3	....
Pennsylvania, Rpt. 1889	10.8	4.4	21.0	11.6
Wisconsin, av. 4 yrs., Rpt. 1891	15.6	16.8	23.8	24.3
Average at 4 stations	15.7	11.1	20.0	16.2

*Average of 3 years.

The table shows that more dry matter and crude protein were lost by drying corn forage in shocks than by ensiling.

302. Corn silage vs. corn fodder.—We have seen that the losses of nutrients by ensiling and drying corn forage are not materially different, tho somewhat favoring silage, and that ensiling a crop tends to decrease rather than increase the digestibility. (**83**) On the other hand, actual feeding trials with dairy cows and steers, reported in Part III, show that silage gives better results than a corresponding amount of dry fodder. (**630, 781**) The difference in favor of silage is doubtless due in part to the fact that cattle usually reject the dry butts of the corn stalks even when cut fine, while in silage they are eaten. Owing to the palatability of this succulence silage-fed animals consume a larger ration and more nutriment is hence available for milk or flesh production after supplying the wants of the body. Like other succulent feeds silage has a beneficial laxative effect and is a valuable aid in keeping farm animals in thrifty condition.

303. The corn for silage.—In the earlier years corn was usually ensiled before the kernels were in the glazing stage. Experience has shown that much sweeter silage is produced when corn is not ensiled until the kernels have hardened and glazed (with the dent varieties when they are well dented). The crop should, however, be cut for silage while most of the leaves are yet green and succulent. The rapid storage of high-quality nutrients which takes place in the later stages of the development of the corn plant is a most important reason for waiting until the crop is practically mature. (**23**) Several stations have determined the yields per acre of green forage and digestible nutrients from southern varieties of corn, which usually do not reach maturity in the North, and from the smaller northern varieties, with the results shown below:

Yield of corn forage at the North from northern and southern seed

	Green weight per acre Southern corn Lbs.	Green weight per acre Northern corn Lbs.	Digestible nutrients per acre Southern corn Lbs.	Digestible nutrients per acre Northern corn Lbs.
Maine, 5 years (Rpt. 1893)	34,761	22,269	3,251	3,076
Penn., 3 years (Rpt. 1892).	32,321	18,606	5,042	4,149
N. Y. (Cornell), (Bul. 16)..	34,060	16,980	4,758	2,953
Wis. (Rpt. 1888)	47,040	24,890	5,414	5,229
Minn. (Bul. 40)	43,000	19,500	3,887	2,911

In each instance the southern corn gave larger yields of green corn per acre. Tho southern corn, which carries a small proportion of grain, is about 8 per ct. less digestible than northern corn, it nevertheless produced more digestible nutrients per acre.[13] However, southern corn should not generally be used for either silage or dry forage except where the climatic conditions permit the ears to develop kernels which reach the glazing stage at time of harvest. When there is an urgent demand for the largest amount of palatable roughage from a given area, the southern varieties have a place in the northern states, in spite of the fact that these types, which will not reach maturity, produce sourer silage. On the other hand, the northern stockman who has hay, straw, or stover at command will aim to fill his silo with a richer feed than southern corn yields, and therefore will use northern dent or flint varieties, which mature. He will plant the crop somewhat more thickly than when grown for grain, but yet so as to secure a relatively large proportion of grain to roughage, and will thus secure a rich silage that materially reduces the amount of concentrates required for his stock.

304. Silage from frozen or drought-stricken corn.—When corn is killed by frost or stricken by drought the silo is the best instrument for preserving all possible nutriment in the crop. When the plants have dried out unduly, water should be added as the silo is being filled to insure the necessary fermentations that preserve the silage.

Hills of the Vermont Station[14] found that silage from frozen corn is not necessarily poorer because of having been frosted, is not dangerous to cows, and does not injuriously affect the milk. He concludes that it is often advisable to allow a crop of immature, watery corn to stand one or two weeks longer than usual, thereby gaining from 6 to 15 per ct. in dry matter should no frost come. Frosted corn should be quickly ensiled, for the storm which usually follows the first fall frosts will wash out much nutriment from the frosted forage, and the winds soon whip off the dried, brittle leaves.

305. Corn fodder or stover silage.—It has been found that cured corn forage, when cut into the silo, thoroly moistened, and well-packed will undergo fermentation similar to that which occurs with green material and may be preserved in a satisfactory manner.[15] Tho usually less palatable than silage from green corn this product has an aromatic silage odor and is readily consumed by stock, with less waste than is dry fodder or stover. This method is now followed by many farmers, especially in the plains region, some even filling their silos 3 times a year—in the fall with green corn or sorghum, and later with the cured forage. The essential points in the process are to add enough water so that the material will pack well and then to tramp it down with especial thoroness; otherwise the mass will spoil. Tho the water may be applied to the cut material in the silo, more even moisture distribution is possible and hence better silage is produced when a stream of water is run into

[13] Jordan, Me. Rpt. 1893. [14] Vt. Rpt. 1906. [15] Del. Rpt. 1903; Vt. Bul. 170.

the blower, thereby wetting the cut fodder before it reaches the silo. Eckles of the Missouri Station[16] states that only about one-third of the total amount of water needed will be taken up by the dry fodder as it passes thru the blower. The remainder should be sprinkled over the fodder in the silo as it is filled. Due to the widely varying water content of field-cured corn forage it is impossible to state definitely the amount of water to be added in such cases. Some recommend adding about an equal weight of water to the forage, others add just enough so that water may be squeezed out of the cut material.

306. Removing the ears before ensiling.—Years ago it was recommended that, instead of ensiling the entire corn plant, the ears be removed and cured elsewhere, and only the stalks and leaves converted into silage. This grain-free silage would then be fed along with more or less of the grain separately saved. This matter was tested by Woll at the Wisconsin Station[17] and Hills at the Vermont Station[18] with adverse results. Hills found that 1 acre of green corn fodder, including ears, reduced to silage was equal in feeding value to 1.26 acres of silage from stalks stripped of their ears and fed with the meal made by grinding the dry ear corn which was produced by the crop.

307. Corn for soilage.—Corn ranks high as a soiling crop on account of its palatability, the high yield of nutrients, and the fact that it remains in good condition for feeding for a much longer period than many other crops grown for soilage. On farms lacking summer silage, feeding corn forage in the green stage as soilage should become general, for during the late summer and early fall pastures are often too scant to enable animals to do their best. In the case of dairy cows such a shortage of feed will cause a decrease in milk flow, which often can not be recovered by subsequent liberal feeding. (**642, 663**) An acre of ripening corn fed in early fall may thus return twice as much profit as if it were held over until winter. For early feeding sweet corn may often be advantageously used.

II. The Sorghums

In the dry-farming districts, from Nebraska to Texas and Arizona, the sorghums, both the saccharine *sorghos* and the non-saccharine *grain sorghums* are of great and increasing importance as forage crops because they are far more drought resistant than corn and the leaves remain green late in autumn. (**235-41**) In 1913 Kansas alone grew 1,633,000 acres of grain sorghum for grain and forage, and 738,000 acres of sorgho, these crops having a total value of over $17,200,000. The sorghums, chiefly the sorghos, are valuable crops in the southern states for hay, soilage, or silage, and are also grown in the northern states, chiefly for soilage.

According to Piper[19] 3 tons of air-dry fodder may be considered a good and 6 tons a large return from the sorghums, while maximum

[16] Mo. Cir. 71. [17] Wis. Rpts. 1891, 2. [18] Vt. Rpt. 1892. [19] Forage Plants, p. 269.

yields may reach 10 tons of dry fodder or 40 tons of green material. Reed of the Kansas Station[20] states that under Kansas conditions the sorghums will produce one-third to one-half more forage per acre than corn.

308. Sorghum fodder and stover.—Thruout regions of scanty rainfall the sorghums are most commonly grown in drilled rows of sufficient width to allow horse cultivation, by which the moisture is conserved and larger yields obtained. When grown in drills, not too thickly, much seed is produced and the stalks are somewhat coarse. Sorghum forage is more palatable when cut before fully matured, but the seed should be allowed to reach the early dough stage, for if cut earlier the plants are watery and contain little nutriment. The crop is cured in shocks, the same as Indian corn, but in the case of the juicy-stemmed sorghos, which cure with difficulty, the shocks should be small. If left in the field in humid regions for 3 months or longer sorgho fodder is apt to sour, due to fermentation of the sugar in the stalks.[21] In sections with ample rainfall the seed is often broadcasted, and the fine-stemmed plants cut with a mower and cured in cocks, the same as the meadow grasses. In the South where the rainfall is ample or on irrigated lands 2 to 3 cuttings of sorghum may be secured in a season if the crop is cut before it matures; in the dry-farming districts the crop is usually cut but once.

The various types of grain sorghums have been previously described. (**235-40**) Of this group the kafirs give the largest yields of the most valuable forage, for they are leafy and the stems are more succulent than those of milo, feterita, or kaoliang. Kafir fodder and stover compare favorably in composition and feeding value with that from corn. Feterita ranks next to kafir for forage, while milo, kaoliang, and shallu have less foliage and more pithy stems. (**772, 861**) The dwarf types of the grain sorghums are often harvested with a grain header, and stock grazed on the standing stalks.

The sorghos with their juicy stalks rich in sugar are grown chiefly for forage. Early varieties, such as Amber cane, ripen earlier than kafir or milo and may be grown wherever corn will mature. Zavitz of the Ontario Agricultural College[22] reports an average plot yield of 16.3 tons per acre from 3 varieties of sorgho tested for 15 years. Snyder of the North Platte, Nebraska, Sub-Station[23] regards sorgho as the best forage plant for the more arid sections of the plains district, where alfalfa can not be grown, being fully equal to good prairie hay in feeding value. Early sorghos have proved the best forage crops on dry farms in northwestern Texas and in Arizona, as they evade drought better than late maturing types.[24] Where rainfall is more abundant the later varieties give a larger yield of forage. The palatable leaves, sweet

[20] Kan. Cir. 28.

[21] Piper, Forage Plants, p. 275.

[22] Ont. Agr. College, Rpt. 1913.

[23] Nebr. Bul. 135.

[24] Conner, Tex. Bul. 103; Clothier, Ariz. Rpt. 1912.

stalks and freedom from dust make sorgho forage a desirable roughage for stock, especially horses. (**499, 861**)

309. The sorghums for grazing, soilage, and silage.—Especially in the southern states, the sorghums, mainly the sorghos, are widely used as summer pasture for horses, cattle, and swine, as they are available at a time when other crops are exhausted or immature. Owing to the danger from prussic acid poisoning, extreme care must be taken in pasturing second growth or stunted sorghum. (**395**) By feeding the green crop as soilage it is the more completely utilized. Tho sorghum may be cut at any time after it reaches a height of 2 to 3 feet, a greater yield of nutrients will be secured when it is allowed to head. The early varieties of sorghos are admirable soiling crops for the northern states. (**421**)

The sorghums formerly had the reputation of producing much sourer silage than corn. Numerous experiments have now shown, however, that when sufficiently matured, both the sorghos and the grain sorghums make excellent silage. Reed of the Kansas Station[25] reports from 2-year trials that silage from kafir or sorgho, ensiled when the seeds were hard, contained less acid than corn silage and was practically equal to corn silage in feeding value. (**632, 782, 870**) He states that the best way to determine when cane or kafir is ready to ensile is to twist the stalk with the hands. When it is so mature that just a very little juice will run out the proper stage has been reached. As with corn, it is preferable to let the crop of cane or kafir stand till after frost rather than ensile it too green. (**303**) The bagasse, or waste of the sorghum syrup factories, should not be wasted, but may be satisfactorily ensiled, as well as the leaves removed before running the stalks thru the mill.

[25] Kan. Cir. 28; and information to the authors.

CHAPTER XIII

THE SMALLER GRASSES—STRAW—HAY-MAKING

I. The Smaller Grasses

The great grain-bearing plants—Indian corn, wheat, rye, barley, oats, rice, and the sorghums—are all members of the grass family, tho they are annuals and require careful cultivation. The smaller grasses are nearly all perennials, thriving without cultivation and producing roughage of high grade. In the humid regions Nature everywhere spreads a carpet of soft, green grass that beautifies the landscape and furnishes an abundance of palatable food for animals. Even in the desert the grasses struggle for existence and yield rich nutriment, tho in meager amount. For recuperating the soil and binding it together and for furnishing food to the domestic animals, the smaller grasses are of supreme importance. In summertime in those regions where grasses flourish, the animals of the farm largely feed themselves, and meat, milk, and wool are produced at the minimum cost for labor.

The smaller grasses may be divided into the sod-formers and non-sod-formers. The sod-formers spread by creeping stems below or above ground. This group includes our most valuable pasture and lawn grasses, such as Kentucky bluegrass and Bermuda grass. The non-sod-formers grow in tufts or bunches, and tho they may increase in size by stooling, do not otherwise spread except by seed. Orchard grass is an example of this class. Certain grasses of the group, as timothy, increase to a limited extent by development and division of bulbs at the base of the stems.

310. Nutrients in grasses at different stages.—Hay from grasses cut at the usual stages of maturity is relatively low in digestible crude protein compared with carbohydrates and fats, and hence should be used with feeds rich in protein. When immature, before the great development of carbohydrates has occurred, the grasses contain a much larger proportion of crude protein. At the Michigan Station[1] Crozier cut growing timothy grass 8 times from one plat, while on another it was cut and cured into hay after making full growth. The hay from the frequently-cut grass was nearly 3 times as rich in crude protein as that from the nearly mature grass cut once. Good of the Kentucky Station[2] found that Kentucky bluegrass, rye, wheat, and oats, cut when only 5 to 8 inches high, contain as high a percentage of crude protein as does alfalfa or the clovers. This shows that immature grasses, such as are gathered by grazing animals, are protein-rich feeds, and explains the favorable

[1] Mich. Bul. 141. [2] Ky. Rpt. 1911-13, p. 9.

results attained when corn, a highly carbonaceous feed, is fed alone to fattening animals at pasture. Crozier secured nearly 4 times as much total dry matter per acre, and also the greatest total yield of crude protein, when the grass was nearly mature. Hence, when grass is cut for hay at the usual stages, the aggregate yield of nutrients is greater than when the same area is kept grazed by animals.

311. Bluegrass, *Poa pratensis.*—Kentucky bluegrass, or June grass, is the common carpet grass of the northeastern United States, easily ranking first for lawn and pasture. By its persistence it often drives red clover, timothy, and other grasses from the meadows and pastures, tenaciously holding its own against all claimants. Appendix Table III shows this grass to be one of the richest in both digestible crude protein and fat, which helps explain the fondness for it shown by stock. Differing from most grasses of the humid regions, mature dried bluegrass is quite readily grazed by animals, thus resembling some of the grasses of the western ranges. With the coming of spring bluegrass pushes forward so vigorously that early in May the fields display a thick, nutritious carpet of green, and a little later the seed heads show. With seed bearing late in May, the plant's energies become exhausted, and bluegrass enters a period of rest which lasts several weeks. During this time there is little growth, and if a midsummer drought occurs the plants turn brown and appear to be dying. They quickly revive with the coming of the fall rains, and again the pastures are green and growing. They have had their rest, and each plant is once more busy gathering nourishment for the coming season's seed bearing. The observant stockman soon learns that it is unwise to rely on bluegrass pasture for a steady and uniform feed supply for his cattle thruout the season. Accordingly he understocks the pasture in spring so that the excess of herbage during May and June may remain to be drawn upon during the midsummer dormant period, or he fully stocks it and makes up the later shortage by supplying silage or soilage. In some districts it has been found profitable to graze bluegrass pastures lightly or not at all in summer, and allow the self-cured herbage to stand for winter grazing. Because of its low, carpet-like growth, Kentucky bluegrass is primarily a pasture grass and should be so regarded. (**419**)

312. Timothy, *Phleum pratense.*—The total acreage in the United States of timothy, called "herd's grass" in New England, is nearly as great as that of all other cultivated hay plants combined, including clover and alfalfa. Timothy is a cool-weather grass, and of vast importance in the northeastern states, where it furnishes probably three-fourths of the hay marketed in the cities. The following points make timothy a favorite with the farmer: Timothy seeds, large and easily recognized, are produced in abundance and long retain their vitality. A field of timothy is quickly established and usually holds out well. The grass seldom lodges, is easily cured into hay, and may be harvested over a longer period than most grasses. Hay from nearly-ripened grass is usually bright, quite free from dust, and satisfies the city buyer, as it is well liked by driving horses, which get most of their nourishment from oats or other grain. (**493**)

Timothy hay is not desirable as the sole forage crop on well-managed farms, because the yield is not large, there is little aftermath, the hay is low in protein, and there are other and better plants which may take its place. On most farms where timothy is now extensively grown, greater use should be made of the legumes, which not only furnish more nutritious hay, rich in protein, but at the same time increase the fertility of the soil. For cattle and sheep legume hay is far preferable to timothy (**623, 764, 861**), and even for horses the legumes may entirely or largely replace it. Fodder corn, hay from the cereals—oats, wheat, rye, or barley—or mixed clover and timothy hay are also desirable substitutes in many cases.

Red or alsike clover should always be sown with timothy, for the combination furnishes more and superior hay, even for horses. Grown together, the hay of the first season will consist largely of clover. With the close of the second season most of the clover disappears and the decaying clover roots will nourish the timothy which .remains, so that a much larger yield of that grass is thereby obtained. Such indirect fertilization of the soil should also increase the nutritive value of the hay, for at the Minnesota Station[3] timothy grown on manured soil contained one-fourth more crude protein than that from the same soil without manure.

313. When to cut timothy.—The most extensive data on the time to cut timothy for hay are those of Waters and Schweitzer at the Missouri Station.[4] During 3 seasons they determined the yield of dry matter in hay from timothy cut at different stages, and also the yield of digestible nutrients, as found by digestion trials with steers, with the results averaged in the table:

Yield of timothy cut at different stages

	Dry matter per acre Lbs.	Digestible nutrients per acre: Crude protein Lbs.	Carbohydrates Lbs.	Fat Lbs.	Total dig. matter Lbs.
Coming into blossom..	3,411	135	1,676	43	1,908
Full bloom...........	3,964	147	1,867	44	2,113
Seed formed.........	4,089	113	1,802	51	2,030
Seed in dough........	4,038	98	1,695	54	1,914
Seed ripe............	3,747	92	1,576	38	1,754

Cutting the crop when the seed had just formed gave the largest yield of dry matter per acre, closely followed by the cutting made when the seed was in the dough, and this in turn by the cutting made when the plants were in full bloom. In view of the large storage of nutrients which continues in the corn plant until the grain is mature (**23**), it at first seems surprising that the last cutting of timothy, made when the

[3] Minn. Bul. 101. [4] Proc. Soc. Prom. Agr. Sci., 1910, pp. 71-98.

seeds were ripe but before they had shattered, yielded 342 lbs. less dry matter than the third cutting. This was due to the partial loss of the lower leaves as the plant matures, to leaching by rain, and to the storage of nutrients in the bulbs at the base of the stems. More important than the total yield of dry matter is the content of digestible nutrients. Owing to decreased digestibility of the later cuttings, at full bloom the crop contained noticeably the most digestible crude protein, carbohydrates, and total digestible matter. While the digestible crude protein had decreased 23 per ct. by the time the seed was formed, there was little or no decrease in the other nutrients up to this stage. Later the yield of both digestible crude protein and carbohydrates fell off markedly. The decrease in total digestible nutrients as the crop matured—a condition opposite to that in the corn crop—is explained both by the reasons mentioned above and by the fact that the maturing corn plant is continuously storing nutrients in the highly digestible grain. Hills of the Vermont Station[5] points out that with the smaller grasses the nutrients stored in the seeds are largely lost to the animal, for the seeds are well protected against mastication and digestion by their small size and hard seed coats.

During 2 years Waters determined the preference of stock for the several cuttings, steers, dairy cows, and sheep being allowed free access to feed racks containing each cutting. Yearling steers with no other feed showed a decided preference for the first cutting over the second and for the second over the third, discriminating sharply against the fourth and especially the fifth. They ate all of the first 3 cuttings before they really began on the fourth or fifth. Those fed liberally on grain and silage did not show such marked preferences for the earlier cut hay. Dairy cows getting grain and silage did not discriminate between the first 3 cuttings, but avoided the later ones. Wethers fed all the corn they would eat showed no preference.

Based on yield of digestible nutrients alone, full bloom appears the best time to cut timothy for hay, but other factors must be considered. In the corn belt, the cutting must often be delayed because the cultivation of corn is then imperative. Immature grass is difficult to cure, the weather early in the season is usually more unsettled, and the ground cooler. When the crop is cut before the large storage of nutrients in the bulbs has occurred, the stand of grass will be impaired, according to Waters. The question is thus complex and must be determined from local conditions. In general we may conclude that for dairy cows, young stock, and sheep, timothy should be cut early, since these animals do not relish hay that is woody and lacks aroma, as does most late-cut hay. For horses and fattening cattle late cutting is favored. These animals subsist mostly on concentrates, and the hay they eat serves more for "filling," as horsemen say. In any case the harvest should not be too long delayed lest the grass become tough and stringy and the seeds

[5] Vt. Bul. 152.

shatter. In trials with early-and late-cut timothy for fattening steers, Sanborn[6] found that late-cut hay gave better returns. The senior author, in an unpublished duplicate experiment conducted many years ago, reached the same conclusion.

314. Red top, *Agrostis alba* or *vulgaris.*—This grass, of several species, is probably suited to a wider range of climatic and soil conditions than any other cultivated grass. A couple of years are required to establish strong plants from seed, but it then forms a close, well-knit, smooth turf, ranking next to bluegrass in this regard. Red top is often indigenous to northern meadows and should be more generally grown. Tracy of the Mississippi Station[7] found no better grass than red top for marshy lands and seepy hillsides. It is especially valuable on damp lands from Canada to the Gulf States and thrives on soil too acid for most other cultivated grasses. At the same time it will withstand considerable drought and endures on poor uplands. Tho not so well liked as bluegrass, red top furnishes good pasture, and yields a palatable hay with fine stems and numerous leaves.

315. Orchard grass, *Dactylis glomerata.*—Tho it does well in full sunlight, this grass thrives better than most others in partial shade. It endures hot weather better than timothy and is well suited to the southern border of the timothy belt. As it starts early in the spring it furnishes valuable pasturage, tho stock prefer bluegrass. It grows in tufts, forming an uneven sod, and hence should be sown with other grasses or clovers, both for hay and pasture. Ripening 2 weeks before timothy, it fits in well with red clover. While late-cut orchard grass makes harsh, woody hay, lacking in aroma, that cut in early bloom is equal to the best of the hay grasses, carrying considerably more crude protein than timothy. This grass is usually persistent, deep rooted, withstands summer droughts well, and continues growth late in the autumn, producing much aftermath.

316. Brome grass, *Bromus inermis.*—For the eastern edge of the northern plains region, stretching from South Dakota to Saskatchewan, brome is the most important cultivated grass, flourishing there as do timothy and bluegrass farther east.

This grass furnishes good crops of hay, equal to timothy in feeding value, for 3 or 4 years after seeding, by which time it usually becomes sod bound and should be renovated by harrowing or shallow plowing. Brome is one of the most palatable of pasture grasses and endures heavy grazing. Tho this grass is one of the most drought-resistant of the cultivated grasses, Snyder[8] found brome unsatisfactory as a hay crop on dry farms in western Nebraska and less productive than the native prairie grasses for pasture, except in seasons with heavier rainfall than usual in that section. Ladd and Shepperd of the North Dakota Station[9] found brome the best grass for permanent pasture, yielding twice as much pro-

[6] Rpt. N. H. Board of Agr., 1880.
[7] Miss. Bul. 20.
[8] Nebr. Bul. 135.
[9] N. D. Bul. 47.

tein and no more fiber than timothy. During a 5-year test, brome grass yielded an average of 2 tons of hay at the Manitoba and 1.25 tons at the Saskatchewan Station.[10] (**496**)

317. The millets.—The millets are rapid growing hot-weather annuals of many races and varieties. Of these, the *foxtail millets,* previously described (**243**), are the type most grown for forage in the United States. In this group are *common millet,* the earliest, most drought-resistant, and, according to Piper,[11] the most widely grown variety; the less drought-resistant *Hungarian millet,* shorter stemmed and with seeds mostly purplish; and *German millet,* late maturing and with nodding heads, which yields more hay, but not of quite such good quality. The foxtail millets are especially valuable as hay crops on dry-farms in the northern plains region. In the more humid regions they are grown chiefly as catch crops, thriving remarkably in hot and even dry weather and reaching the harvest period late in August or September. For millet hay of fine quality heavy seeding should be practiced. Millet grass designed for hay should be cut as soon as the blossoms appear, to prevent the formation of the hard, indigestible seeds. Thickly-seeded, early-cured millet hay is useful for cattle and sheep feeding. (**798, 861**) Since millet hay is sometimes injurious to horses, it should be fed sparingly and under close supervision. (**498**)

Japanese barnyard millet (*Echinochloa frumentacea*), a close relative of the common barnyard grass, has often been advertised as "billion dollar grass." This plant is much coarser than the foxtail millets and under favorable conditions yields large crops of coarse forage. Lindsey of the Massachusetts Station[12] found this millet less satisfactory than corn for soilage because it is more woody and less drought resistant. For hay it is inferior to the foxtail millets. The *broom-corn millets,* previously described (**243**), are grown chiefly for seed production, as the yield of forage is low and the stems woody. *Pearl millet* (*Pennisetum glaucum*), also called pencillaria or cat-tail millet, is adapted to the same conditions as the sorghums, which have largely displaced it in both the semi-arid regions and the South. As a soiling crop this tall growing grass has value in the southern states, yielding 3 or more cuttings in a season. It should be cut when 3 to 4 feet high, before the stems become hard.

Teosinte (*Euchlaena Mexicana*), a giant millet resembling sorghum, requires a rich, moist soil and is too tropical to have value north of the southern portion of the Gulf States. The culture of this grass is decreasing in the United States, because on moderately fertile soils it yields less than sorghum, and on rich land less than Japanese cane.[13]

318. The small grains for forage.—Oats, barley, wheat, rye, and emmer may all be successfully used for the production of hay, soilage, and pasturage. In 1909 over 4,300,000 acres of small grains were cut for hay

[10] Canada Expt. Farms, Rpts. 1902-6.
[11] Forage Plants, p. 288.
[12] Mass. Bul. 133.
[13] Piper, Forage Plants, p. 303.

in the United States, nearly as large an acreage as was devoted to alfalfa, and about 4 times that of the millets.[14] Over half this area was in the Pacific coast states, wheat and barley being grown in Washington and chiefly barley in California. More than 40 per ct. of all the hay grown in the southeastern coast states, from North Carolina to Louisiana, is from the small grains. When intended for hay, the cereal grasses should be cut while the grains are in the early milk stage, at which time the stems and leaves may be cured into a bright, dust-free hay of good quality. Bearded wheat, barley, and rye should be cut before the awns harden. Cereal crops which have lodged badly because of overrich soil or excessive rainfall may often be advantageously converted into hay. **(494)**

In the North, fall-sown rye and wheat furnish excellent late fall and early spring pasture and soilage, while spring-sown oats and barley provide green forage in early summer. Barley is the best cereal grass for late summer seeding, since the young plants do not rust so readily as do other cereals. In the southern states fall-sown grains, including winter oats, may be pastured thru the winter, and if not cropped too closely or too late will still yield considerable hay or grain. At the Alabama (Canebrake) Station[15] a fall-seeded barley field yielded over 11 tons of green forage per acre by the following March. In southern Kansas it was found that fall-sown wheat pastured by cows during mild weather in winter gave a grass flavor to winter butter. The bad flavor which green rye imparts to milk may usually be avoided by grazing the cows thereon for but 2 or 3 hours immediately after milking. In the northern states the cereal grain plants are not as extensively used for hay and pasture as they should be.

A field sown to rye, wheat, oats, or barley for temporary pasture may be changed to a permanent one by sowing clover and grass seed thereon early in spring in the usual manner. The grass and clover plants will then begin growth under shelter of the young grain plants. Stock may be turned into such pastures to graze on the cereal plants regardless of the young grasses and clovers, but should be kept off the field immediately after rain while the ground is soft. The cattle will tramp out some of the tiny grass plants, but will do no permanent harm. The young grass and clover plants will grow rapidly, and as the cereal plants die will spread until they form a dense, permanent sod. Such double seeding gives the earliest possible summer pasture of rye, wheat, barley, or oats, followed by the more permanent one of mixed grasses and clovers.

If ensiled when the kernels are just past the milk stage or slightly earlier, the cereals make silage of fair to good quality. The crop should be run thru a silage cutter and unusual care taken in tramping down the mass to force as much air as possible out of the hollow stems. Hooper of the Kentucky Station[16] found rye silage relished by cows and not injurious to the flavor of the milk if fed several hours before milking. **(636)**

[14] U. S. Census, 1910. [15] Ala. Bul. 9. [16] Ky. Exten. Cir. 31.

319. Minor northern grasses.—*Canada bluegrass* (*Poa compressa*) will yield fair pasturage or small crops of hay on poor or thin soil where Kentucky bluegrass fails. It withstands close grazing and is considered excellent for fattening cattle. This grass is important in Ontario and New York and is also abundant in Pennsylvania, the Virginias, and Maryland.

Fowl meadow grass (*Poa flava*), a close relative of Kentucky bluegrass, thrives in the northeastern states on wet land subject to overflow where even red top and alsike clover are killed out. Hills of the Vermont Station[17] reports yields on such wet meadows of 1.2 to 2.5 tons per acre of hay which is as well relished as upland hay.

Meadow fescue (*Festuca elatior*), a tufted, long-lived perennial grass, is adapted to practically the same area as timothy, which excels it for hay. Tho it thrives best on rich moist land, the largest acreage is grown in eastern Kansas.[18] It is best as a pasture grass, starting growth early in the season and continuing till late in the fall. As the seed is high-priced, it is usually sown in mixture with other grasses for permanent pastures.

Italian rye grass (*Lolium multiflorum*) and *English rye grass* (*Lolium perenne*) are short-lived, rapid growing perennials. Tho of great importance in Europe they are little grown in this country, except in the humid region of western Washington and Oregon, where they are among the best pasture grasses.

Slender wheat grass (*Agropyron tenerum*), known in Canada as western rye grass, the only native North American grass which has proved valuable under cultivation, is giving satisfaction in the northern plains district.[19]

320. Bermuda grass, *Cynodon Dactylon.*—This low growing, creeping grass is to the cotton belt what Kentucky bluegrass and timothy combined are to the northeastern United States. Bermuda grass forms a dense, soil binding sod, which covers the southern fields with a carpet of green from April to October as pleasing to the eye of the stockman as it is to the animals grazing thereon. It serves best when closely grazed, as otherwise it becomes tough and wiry. Because of its aggressiveness, it drives most other grasses out in summer, but lespedeza or white clover will flourish in spots among this grass and improve the pasture. For winter pasture, when Bermuda fails, the Bermuda sod may be seeded to bur clover, hairy vetch, or Italian rye grass. (**354, 359, 319**) Piper[20] states that good Bermuda pasture will carry 1 cow to the acre and the best mixed Bermuda and lespedeza pasture will graze 2 animals per acre during the summer. The Louisiana Station[21] grazed 30 head of cattle of all ages on 17 acres of Bermuda grass pasture, mixed with other grasses and some lespedeza, with no other feed from March to November. Killebrew[22] states that on the best alluvial soils 1 acre of Bermuda

[17] Vt. Bul. 137.
[18] Ten Eyck, Kan. Bul. 175.
[19] Piper, Forage Plants, p. 219.
[20] Forage Plants, p. 243.
[21] La. Bul. 72.
[22] La. Bul. 72.

pasture will graze 10 sheep for 8 months. Bermuda pastures are best utilized by subdividing them and turning the stock from one lot to the other. Tho primarily a pasture grass, on rich soil Bermuda gives good yields of hay. While 3 to 4 tons of hay per acre have been secured in 2 to 3 cuttings, according to Piper[23] the average yield does not exceed a ton per acre. (**497, 625**) The stout rootstocks when plowed up are readily eaten by hogs, and in the tropics, when the top growth is scanty, are often pulled up and fed to horses.

321. Johnson grass, *Andropogon halepensis.*—In the South this relative of the sorghums is the worst weed of the cotton planter and at the same time the best meadow grass for many sections.[24] Spreading by seed and vigorous creeping rootstocks, it can be eradicated only with great difficulty, and hence it is not as a rule sown on clean fields. On rich soil in the southern states 3 cuttings of good quality hay may be secured, if cut before maturity. Six tons of Johnson-grass hay per acre are reported, tho the annual return usually ranges from 2 to 3 tons. (**497, 626**) As the grass soon becomes sod bound, it should be plowed every 2 or 3 years. While this coarse grass is not well suited for pasture, it may be cut once each month for soilage during the summer season. The rootstocks of Johnson grass are readily eaten by stock, especially hogs, fields sometimes being plowed in Texas to furnish winter feed.[25]

322. Sudan grass; Tunis grass.—*Sudan grass* (*Andropogon sorghum,* var.), a close relative of the sorghums, is a tall annual grass introduced into this country by the United States Department of Agriculture in 1909. It closely resembles Johnson grass, but has broader and more numerous leaves and fortunately has no creeping rootstocks, so that it cannot become a pest. Sudan grass grows 6 to 10 feet high in cultivated rows, and 4 to 5 feet when sown broadcast. For so rank a grass the stems are fine, being seldom larger than a lead pencil. The hay is equal or even superior to millet and can be fed to all classes of stock without injury, and the plant is also well suited for soilage.[26] In composition it closely resembles timothy and Johnson grass. Thruout the northern states it yields only one cutting, but farther south it may be cut twice or even more. Sudan grass is adapted to the same conditions as the sorghums, and being drought resistant will doubtless prove one of the most valuable forage crops for the western portion of the plains region, from central South Dakota to Texas. According to Vinall,[27] in 1913, with unusually severe drought, yields ranging from 1.25 to 5.0 tons were secured in this section without irrigation. As Sudan grass is a warm-weather grass it does not flourish at high altitudes or in the ex-

[23] Forage Plants, p. 242.
[24] Wing, Meadows and Pastures, pp. 355, 401.
[25] Piper, Forage Plants, p. 246.
[26] Piper, Forage Plants, p. 281.
[27] U. S. Dept. Agr., Farmers' Bul. 605.

treme northern states. In the corn belt and in the east central states where alfalfa, clover, and timothy flourish, its chief value will be as a catch crop in place of millet. Under irrigation in the Southwest yields of 7.8 to 9.8 tons have been secured, which indicates its value as a forage to feed with alfalfa.[28] Along the humid Gulf Coast, Sudan grass does not thrive. Since this grass crosses readily with the sorghums and bears seed closely resembling those of Johnson grass, unusual care is necessary to ensure its purity.

Tunis grass, another variety of *Andropogon sorghum* which has been recently introduced into this country, is less leafy and vigorous than Sudan grass, which so far has surpassed it in value for all sections.[29]

323. Japanese cane; sugar cane.—Because of its heavy yields, Japanese cane, a slender stemmed variety of the common sugar cane, *Saccharum officinarum,* is one of the cheapest forage crops that can be grown in the Gulf states, and possibly in southern California. Scott[30] reports that in Florida it furnishes good pasture for cattle and hogs from November to March but is killed by grazing after growth starts in the spring. Stock first eat the green blades and then the stalks, leaving only the short stubble. The crop may be cured as dry fodder and makes good silage. Scott[31] states that yields of 25 to 30 tons of green forage per acre are not unusual.

The tops and leaves of common sugar cane, removed on harvesting the cane, also make satisfactory forage for live stock. Dodson and Staples of the Louisiana Station[32] state that cattle ate silage from sugar-cane tops well. They point out the great loss which occurs when this by-product is not utilized by feeding it to stock.

324. Other southern grasses.—*Crab grass* (*Digitaria sanguinalis*), an annual, weedy, volunteer grass, furnishes more forage in the Gulf states than any other grass. Springing up after early crops, it furnishes fair hay or good fall pasture.[33] *Carpet grass* (*Axonopus compressus*), a perennial with creeping rootstocks, probably ranks next to Bermuda as a pasture grass for the southern half of the cotton-belt, being especially useful on damp lowlands.

Para grass (*Panicum barbinode*) is a coarse, tropical grass with stout runners which may reach 15 to 40 feet, taking root at intervals. It produces several cuttings annually, yielding as much as 4 tons of hay per acre at a single cutting.[34] *Guinea grass* (*Panicum maximum*), a perennial with short creeping rootstocks, furnishes 4 to 6 cuttings in the Gulf region. Tracy[35] states that 1 acre of this grass will carry 4 head of cattle thru the season by soilage, or 3 head by grazing. *Rescue grass* (*Bromus unioloides*), a short-lived perennial, is probably the best grass for temporary winter pastures on rich land in the South. On such soil

[28] U. S. Dept. Agr., Farmers' Bul. 605.
[29] U. S. Dept. Agr., Farmers' Bul. 605.
[30] Fla. Bul. 105.
[31] Wing, Meadows and Pastures, p. 360.
[32] La. Bul. 143.
[33] Hunt, Forage and Fiber Crops, p. 117.
[34] Piper, Forage Plants, p. 254.
[35] U. S. Dept. Agr. Farmers' Bul. 300.

it grows large enough to be cut for hay.[36] *Natal grass* (*Tricholaena rosea*), when once seeded in the Gulf section, volunteers from year to year, coming after early crops and producing excellent fall and winter grazing and good hay.[37]

325. Wild and marsh grasses.—Along certain sections of the Atlantic coast are extensive salt marshes, the best of which are cut for hay at low tide, yielding 0.5 to 1 ton per acre. Lindsey[38] of the Massachusetts Station found such hay from 10 to 18 per ct. less valuable than average mixed hay from the cultivated grasses for dairy cows. (**627**) In all humid regions of the country are large fresh water marshes, some of which are covered with the more nutritious true grasses, while in others the rushes and sedges predominate. Such marsh hay as blue joint, *Calamagrostis Canadensis,* cut before maturity, nearly equals timothy in value.

The prairies of the Great Plains and the grazing ranges of the West support numerous native grasses that furnish excellent pasturage and hay equal to timothy when the growth is rank enough to be cut. (**495, 624, 761, 861**) The sedges and rushes of the mountain states are richer in nutrients than those of the eastern states.[39]

326. Mixed grasses.—No matter how valuable, no single variety of grass should be grown in permanent meadows or pastures, but always a mixture of several kinds in combination with the clovers. In the North a combination of red top, timothy, and orchard grass, together with alsike and medium red clover, will yield a larger tonnage of aromatic, palatable hay than is possible from any single variety. The variety and proportion of grasses and clovers to be included in such a mixture will depend on climate and soil, and can not be discussed in this work. In case of doubt as to the mixture to sow the stockman should consult the experiment station of his state, which understands the local conditions, and should also observe the growth of the different varieties on his own and adjacent farms. It must be remembered that the presence or absence of sufficient plant food—nitrogen, phosphoric acid, potash, and lime—determines and regulates not only the yield of forage, but also, in large degree, the particular species or varieties of grasses and legumes which do or may grow in any given field.

327. The abuse of pasturage.—Stockmen rely too blindly upon pastures for the maintenance of their cattle during half the year. But a few centuries ago the inhabitants of Great Britain trusted to the growth of natural herbage for the support of their stock not only in summer but thruout the entire year. If their animals, foraging for themselves as best they could, survived the winter, all was well; if they died from starvation, it was an "act of God." We have abandoned the crude practices of our ancestors, and now carefully store in barns an abundance of feed for flocks and herds during winter's rigor. We are amazed that

[36] Piper, Forage Plants, p. 257.
[37] Wing, Meadows and Pastures, p. 366.
[38] Mass. Bul. 50.
[39] Wyo. Bul. 78.

our ancestors were so improvident as to gather no winter feed for their cattle. By turning cattle to pasture in spring and letting them forage as best they may until winter we show that all the barbaric blood has not yet been eliminated from our veins. If the summer rains are timely and abundant the cattle are well nourished on these pastures; if drought prevails they suffer for food as surely, and often as severely, as did the live stock of England in winter, ages ago. To suffering from scant feed there is added the heat of "dog days" and the ever-present annoyance of blood-sucking flies. Our stockmen will never be worthy of their calling, nor their flocks and herds yield their best returns, until ample provision is made against drought-ruined pastures in summer.

The decline in yield of permanent pastures is often attributed to over grazing. This is undoubtedly a most important cause of the depletion of some of the western ranges, but heavy grazing is not necessarily injurious to pastures in humid regions. Carrier and Oakley of the Virginia Station[40] found in a 5-year test that bluegrass pastures heavily grazed were more productive than those lightly grazed, as weeds were prevented from encroaching. Testing the effect of the often-recommended system of alternate grazing of pastures, they found insufficient increase in yield, measured by the gains made by the steers, to justify the extra expense. In America we have not begun to utilize our pastures as is done in Europe, where stock is still grazed on land worth several hundred dollars an acre. By proper fertilization, reseeding with suitable mixtures of grasses and clovers, and keeping down brush and weeds the productivity of pastures may be both greatly and profitably increased.

Because of over-stocking and over-grazing under the system of free and unrestricted grazing, the carrying capacity of many of the western ranges has been seriously reduced. The day of the "all-year-round" open range is now almost past, and in its place has come a system under which, by the use of supplemental feed for periods of summer drought or winter storm, the natural forage is utilized much more wisely than before. With ranges thus handled the enormous losses of cattle and sheep from starvation, which were all too common in the old range days, are prevented. The improvement under a rational system of grazing has been demonstrated on the grazing areas under the control of the United States Forest Service[41] and by the studies of Thornber and Griffith at the Arizonia Station.[42] Fencing or otherwise restricting the range, the development of convenient water supplies, the conservation of the range during periods of seed ripening and germination, and the prevention of soil erosion have greatly increased the carrying capacity of such areas. Thornber cites an instance where, 6 years after fencing, a range of over 25 square miles carried nearly twice as many cattle as before fencing. The animals also kept in excellent condition thruout the year, while formerly they lost weight rapidly during the winter and occasionally some died from shortage of feed.

[40] Va. Bul. 204. [41] Barnes, Western Grazing Grounds. [42] Ariz. Bul. 65.

II. Straw and Chaff

As the cereals and other plants mature, the nutrients which have been built up in the green portions of the plants are in large part stored in the ripening seed, thus exhausting the stems and leaves of easily digested nutrients and leaving in them the resistant woody fiber, or cellulose. All straws are therefore much lower in nutritive value than the same plants cut for hay before maturity. The feeding value of each class of straw may differ widely, depending on the stage at which the crop was cut, the care with which it was cured, and the amount of the more nutritious grasses and weeds present.

328. Straw and chaff of the cereals.—Straw is poor in crude protein and fat, and high in woody fiber, or cellulose, a carbohydrate that requires much energy for its digestion and disposal. (**80**) Accordingly, it should be fed but sparingly to animals at hard work, fattening rapidly, or giving a large flow of milk. For animals at light work, fattening slowly, or giving only a little milk some straw can often be advantageously used. Straw is particularly useful in winter with horses that are idle and cattle that are being carried over without materially gaining in weight. Heat is one of the requirements of such animals, and the large amount of energy expended in masticating, digesting, and passing straw thru the body finally appears as heat which helps warm the body. (**501, 502**) The stockman who understands the nature and properties of straw will usually be able to make large use of it. In Canada and Europe pulped roots and meal are often mixed with straw, which is cut or "chaffed," and the moist mass allowed to soften and even to ferment slightly. It is then readily consumed in large quantities by cattle and sheep with satisfactory results. In many districts of Europe horses are fed cut straw mixed with their concentrate allowance. In trials at the Indiana Station, Skinner and King found that oat straw was as satisfactory as clover hay for satisfying the desire for dry roughage of steers otherwise fed shelled corn, cottonseed meal, and corn silage. When fed with corn silage, oat straw is equal to corn stover for fattening lambs. (**778, 862**)

Oat straw with its soft, pliable stems is the most nutritious, followed by barley straw. Wheat straw, being coarse and stiff, is not so readily eaten by cattle, tho spring-wheat straw is of more value than that from winter wheat. Rye straw, harsh and woody, is better suited for bedding than for feed. The chaff of wheat and oats contains more crude protein than does straw, and forms a useful roughage when not unduly contaminated with dust, rust, or mold.

329. Straw from the legumes and other plants.—Straw from the legumes contains considerably more crude protein and less fiber than that from the cereals and is more digestible. In a trial by H. W. Mumford at the Michigan Station[43] field-bean straw proved superior to oat straw for fattening lambs. Carmichael of the Ohio Station[44] found that

[43] Mich. Bul. 136. [44] Ohio Bul. 245.

lambs fed corn and linseed meal made better gains on soybean straw than on corn stover, tho refusing 41 per ct. of the soybean straw. Field-pea straw, with its finer stems and often still carrying some seed, has a higher value than the coarser straw from field beans or soybeans. While not especially desirable, flax straw may be fed in the absence of better roughage. The statement that the stringy fiber of flax forms indigestible balls in the stomachs of farm animals is unwarranted, since it is digested the same as other fibrous matter, such as the lint of cotton and the pith of corn stalks. Green colored straw from immature flax plants should be fed with extreme caution, as it may contain large amounts of prussic acid. Ince of the North Dakota Station[45] found the amount of this poison in straw or chaff from ripe flax plants so small that it could not cause trouble if fed in moderate amounts. Straw containing considerable flaxseed or weed seeds has increased value. Wilson of the South Dakota Station[46] advises against feeding flax straw to pregnant animals.

Buckwheat straw is of low value and may cause digestive disturbances if fed in large amount.[47] Nelson of the Arkansas Station[48] states that properly cured rice straw is excellent for stock.

III. Hay-making

Thruout the temperate regions hay from the grasses and legumes serves as the common roughage for all the larger animals that produce food or perform labor for man. The conversion of green forage into hay must have been the first great step in changing the nomad herdsman into the farmer-stockman. In the United States for the year 1914, over 49,145,000 acres of land produced 70,071,000 tons of hay worth on the farm $779,068,000.[49]

330. Nutritive value of dried grass.—To determine the effect upon its feeding value of drying young grass Armsby[50] conducted a trial at the Wisconsin Station and a later test at the Pennsylvania Station. In the Wisconsin experiment the grass was cut when 9 to 10 inches high, and in the Pennsylvania trial short grass was cut with a lawn mower. In each case half the grass was fed fresh to a cow, and the other half later fed to the same cow after being carefully dried in the sun on canvas in the first trial, and in the second, over a steam boiler. There was no difference in the amount either of milk or butter fat produced on the dried and the fresh grass, showing that perfectly dried grass yields as much nutriment as when fed in the fresh condition. In actual hay making, however, more or less of the finer portions of the plant is always lost.

Exposure to the sun reduces the palatability by bleaching and causes a loss of aromatic compounds, dew works injury, and rain carries away the more soluble portions. (**56**) Thus, while the dried grass may theoretically equal the fresh forage, in practice it falls short.

[45] N. D. Bul. 106.
[46] Breeder's Gaz., 59, 1911, p. 19.
[47] Pott, Ernähr. u. Futter., II, p. 329.
[48] Ark. Bul. 98.
[49] U. S. Dept. Agr., Yearbook 1914.
[50] Penn. Rpt. 1888.

Stöckhard[51] cured one sample of meadow hay in 3 days and left another in the field for 13 days in alternate wet and dry weather. Analysis showed that the weathered hay had lost 12.5 per ct. of its total dry substance, representing one-fourth of its original nutritive value. Märcker[52] found the loss in meadow hay exposed to prolonged rain to be 18.4 per ct. of the dry substance. Even greater losses occur when legume hay is exposed to rain. According to Wolff[53] 40 per ct. of the dry matter of clover hay may be extracted by cold water. Headden at the Colorado Station[54] analyzed alfalfa hay before and after exposure to 3 rains, aggregating 1.8 inches, with the following results:

Composition of alfalfa hay before and after exposure to rain

	Crude protein Per ct.	Fiber Per ct.	N-free extract Per ct.	Fat Per ct.	Ash Per ct.
Hay not rained on....	18.7	26.5	38.7	3.9	12.2
Hay damaged by rain.	11.0	38.8	33.6	3.8	12.7

It will be noted that the damaged hay contained much less crude protein, considerably less nitrogen-free extract, and much more fiber. Of the original nutrients 60 per ct. of the crude protein, 41.0 per ct. of the nitrogen-free extract, and 33.3 per ct. of the fat,—or 31.7 per ct. of the total dry matter was lost. The actual damage was even greater, for the nutrients lost were those most soluble and hence most easily digested.

331. Hay-making.—The widely varying character of grass and legume crops, the dryness and the temperature of the soil of the meadows, the humidity of the atmosphere, and the intensity and continuity of sunlight and heat, are all modifying factors that combine to make the curing of forage crops into hay one of those arts which cannot be very helpfully discussed in books. However, it is highly important to understand the principles underlying hay-making and have in mind the procedures under the leading systems. Each can then adapt his practice to his own conditions.

In curing hay under ideal conditions, 3 different processes take place which are well summarized by Piper:[55] (1) A reduction in water content to about 15 per ct. (ranging from 7 per ct. to 25 per ct.), (2) fermentations of the hay produced by enzymes, which usually develop a characteristic aroma, (3) more or less bleaching, due to destruction of the green chlorophyll by sunlight, the bleaching being increased by the action of the dew.

The ends sought in making hay are to secure bright green color, good aroma, retention of the leaves and other finer parts (especially in legumes), and freedom from dust and mold.

When it is desired to secure prime hay without regard to expense, it is mown as soon as the dew is off in the morning, allowed to lie in the

[51] Wolff, Farm Foods, Eng. ed., p. 155.
[52] Loc. cit.
[53] Farm Foods, Eng. Ed., p. 160.
[54] Colo. Bul. 111.
[55] Forage Plants, p. 24.

swath until dry on the surface, then turned, if heavy, by hand or by hay tedder, or raked into loose windrows. Before the dew falls, it is bunched into well-made cocks and, if sufficiently cured so that it will not mold, is allowed to remain until it has passed thru a sweating process. With legume hay it is well to protect the cocks from rain by hay caps. After sweating, it is usually necessary to open the cocks carefully and in large flakes to avoid shattering the leaves. These flakes rapidly give off their moisture, which by this time has spread evenly to all parts, and the hay is soon ready for the barn. Where the hay was green or damp with rain when cocked, it may be necessary to open the cocks the next morning, recocking before nightfall if still not dry enough. By this system the hay is exposed but little to the bleaching action of the sun and dew, and there is no marked loss of aroma, which, tho unweighable, has real value in rendering hay palatable. Before the partly dried plants are piled into cocks, the leaves will have dried out more than the stems. As the leaves and stems remain alive for some time after having been severed by the mower, if the hay is cocked before the leaves are entirely dried out and thereby killed, they will continue to draw water from the stems. This process is especially important with the legumes, which have thick stems that are usually quite succulent, while the leaves dry rapidly and become brittle and shatter badly. Hay cocked in the afternoon entraps much warm air, and the mass remains in a condition favorable to the transpiration, or giving off, of moisture during the night. The heat yielded by the plant while still carrying on its life functions and the warm air entrapped by grass gathered in the afternoon should not be confused with the heat which may develop in partially cured or damp hay thru fermentation, caused by molds and bacteria.

Hay put into the barn when so dry that it will not pack well, is not in first class condition. It should be mowed away with just that amount of moisture which allows it to settle compactly when treaded down. Salt and lime scattered over hay when put into the mow tend to prevent fermentation and check the growth of molds. Salt also renders it more palatable. These materials are not essential, but are helpful, especially when storing partially cured hay during bad weather. Damp hay may be improved by placing it in alternate layers with dry straw. The straw absorbs moisture as well as aroma from the hay, so that cattle the more readily eat both straw and hay. Hay from second-growth grass, or aftermath, is rich in nutrients, but it is made at a time when the ground is often damp and cool, the days short, and the heat of the sun weak. This combination renders the curing of aftermath difficult, and the product is apt to be of less value than first-crop hay. Cured under favorable conditions, aftermath hay is excellent.

New-made hay is laxative and should not be fed to horses, since it makes soft flesh and may cause colic. Not until the sweating process has been completed in the mow and the mass cooled off can new-crop hay be fed with entire safety.

332. Making hay under favorable conditions.—On farms where large acreages of hay are made, it is often unprofitable to cure the crop in cocks, owing to the labor involved, even tho better hay is thus secured. Under a system often followed the hay is mown in the morning and by frequent tedding and turning is housed before the dew falls at night. When the weather is very dry, even clover and alfalfa, if dry on the surface of the swath, are often raked directly into small windrows by a side-delivery or other rake, without previous tedding. After curing here for a few hours the hay is loaded from the swath by the hay loader, or, in the West, is hauled to the stack with a sweep rake.

Another method is to cut the crop late in the afternoon so that the dew will not materially affect the plants during the night, because they are but little wilted. Even should rain come it will cause far less injury than if the plants were partially cured. The following day, by aid of tedder or rake, the drying is hastened as much as possible, and the hay placed under cover or in the stack before night.

When these methods are followed with the legumes, it is impossible to avoid much loss of the leaves, for when curing in the swath or windrow the leaves become dry and brittle long before the stems are dry enough to allow the hay to be stored. Headden of the Colorado Station[56] found that 40 to 60 per ct. of the weight of the alfalfa plant is in its leaves, which carry four-fifths of the crude protein and over half of the nitrogen-free extract and fat. Three-fourths of the fiber, or woody portion, of alfalfa is in the stems. He further found that in the dry climate of Colorado, with all conditions favorable, for every ton of alfalfa hay taken off the field not less than 350 lbs. of leaves and stems was wasted, and with unfavorable conditions and careless handling there was a loss of as much as 3,000 lbs. In other words, it is possible for more hay to be lost than is garnered.

In dry climates, to avoid undue loss of leaves and yet save the labor involved in cocking the hay by hand, especially with alfalfa and clover, the hay is not allowed to cure long in the swath, but is raked into windrows in the afternoon and allowed to remain there over night. The next morning after the dew is off the hay is bunched with a rake and should be ready to haul by afternoon.[57]

333. Aids in curing hay.—Besides hay caps to protect the cocks of curing hay from rain, especially with such crops as cowpeas and peanuts which are thick stemmed and succulent, devices are often used, under unfavorable weather conditions, to allow the air to penetrate the cocks.[58] The simplest is the perch, which is a stake about 6 feet high with cross arms 2 to 3 feet long. This is driven into the ground so that the cross arms do not touch the earth, and the green or partly-cured plants are then piled on the frame so as to make a tall, slender cock. A somewhat

[56] Colo. Bul. 110.
[57] Jardin and Call, Kan. Bul. 197.
[58] Adapted from Piper, Forage Plants, pp. 26-28.

more elaborate device, the pyramid, consists of 3 or 4 legs joined at the top and sometimes shaped so they can be driven firmly into the ground. This permits of making a larger cock with an air space in the interior. Other frames combine the characteristics of the perch and the pyramid. Often such crops as cowpeas are stacked before thoro curing, rails supported at the ends being used to separate the stack into layers with air spaces between.

In Mississippi when the heavy rainfall menaces some of the alfalfa cuttings Gurler[59] constructs sleds of boards and scantlings, about 5 by 5 feet, on which the alfalfa, cured as much as possible, is cocked and covered with muslin caps. These large cocks usually remain untouched, or when the alfalfa is very green when cocked they may be opened out in flakes to dry the more quickly. When cured, the cocks, still on the sleds, are drawn direct to the barn or baler.

334. Brown hay.—Where weather conditions render it impossible to make good hay by the usual methods, the crop may be preserved as "brown hay." The fresh-cut material may be made into cocks at once, each layer being thoroly compacted by tramping. The curing is brought about by the fermentation which takes place in the moist mass. After the cocks have stood for 48 to 60 hours they are opened out for a time to allow the vapor to escape, and the brown hay may then be safely housed. More commonly the crop is somewhat cured in the air and then piled in compact stacks where it remains until fed. The crop must not be too dry when stacked or it can not be packed firmly enough, and the undue amount of air present permits the fermentation to produce sufficient heat to char the mass. If the crop is too green, it will not cure, but be converted into stack silage. Pott[60] recommends stacking when about one-fourth of the water has been lost by curing. At this stage it will not be possible to wring any water from a wisp of the grass stems. The crop should not be stacked when wet with rain or dew.

The product will vary in color from dark brown to nearly black, depending on the extent of the fermentation. The darker the color the lower will be the feeding value. Brown hay of good quality has an aromatic odor and is well liked by stock. However, as the losses of nutrients are greater than when the crop is cured into hay by the usual methods, the process can be recommended only when the weather is unusually unfavorable.

335. Spontaneous combustion.—It is now generally conceded that spontaneous combustion may occur in partly dried clover or grass. Hoffmann[61] states that when hay heats, oxygen is taken from the air, and organic matter is transformed into carbon dioxid and water. The water thus formed further moistens the hay, which then ferments, owing to the presence of bacteria. The first fermentation may cause a temperature of 133° F., and this leads to a higher one of about 194° F. When

[59] Information to the authors.

[60] Ernähr. u. Futter., I, 1904, p. 211.

[61] Expt. Sta. Rec., 10, p. 880.

this temperature is reached, the hay heats still more and charring goes on rapidly. All these processes together destroy at least half of the material present. According to tests, clover hay will ignite at 302° to 392° F. The temperature may become sufficiently high for spontaneous combustion, which is indicated by the hay becoming darker in color and finally black, by sooty odors, and by smoke. It is probable, tho not certain, that spontaneous combustion does not occur in partially dried clover or grass even if quite damp, provided it carries only its own natural moisture. Spontaneous combustion generally, and possibly always, occurs in stored or stacked hay that carries external moisture in the form of dew or rain. The trouble is best avoided by never placing hay material in stack or barn when it carries excessive moisture or is wet with dew or rain. When curing hay heats dangerously high it should be compacted and covered with other material and all other possible means taken to shut out the air.

336. Measurement and shrinkage.—Woll[62] states that 420 cubic feet of timothy or 500 of clover hay in the mow equals 1 ton. Wheeler and Adams of the Rhode Island Station[63] found that field-cured, mixed red top and timothy hay, containing from 25 to 29 per ct. water when placed in the barn, showed a shrinkage of from 15 to 20 per ct. of the original weight when later removed. Jordan of the Pennsylvania Station[64] found that timothy hay stored in the mow shrank on the average 22 per ct. and red clover 37 per ct. Wilson of the Arizona Station[65] found the shrinkage of stacked alfalfa hay to range from 11 to 23 per ct. Sanborn of the Missouri Station[66] estimates that a hay stack 12 ft. in diameter has 33 per ct. of its contents in the surface foot where it is more or less exposed to the weather. A stack of second-crop clover lost 30 per ct. in weight between early August and the following March, 17 per ct. of this loss being water and 13 per ct. dry matter.

[62] Handbook for Farmers and Dairymen.

[63] R. I. Bul. 82. [64] Penn. Bul. 5. [65] Ariz. Rpt. 1907. [66] Mo. Bul. 25, 1st series.

CHAPTER XIV

LEGUMINOUS PLANTS FOR FORAGE

The cereal grains and the grasses are all rich in carbohydrates compared with crude protein, and thus serve primarily as sources of energy and fat in nourishing animals. The legumes comprise the great group of food-bearing plants characterized by their high content of crude protein, and therefore serve especially for building the muscles and the other protein tissues of the body. (**92-4**) Their great value is due not only to this but also to their richness in lime (**97-8**), which is required in large amounts by growing animals and those which are pregnant or giving milk. (See Appendix Tables I and VI.)

The leguminous roughages are therefore admirable supplements to the cereal grains, and stand in marked contrast to forage from corn, the sorghums, and the smaller grasses, all of which, if cut when nearly mature, furnish forage low in crude protein and only poor to fair in lime. Thru the proper utilization of roughage from the legumes the amount of concentrates needed to provide balanced rations for farm animals may be greatly reduced. Indeed, for many classes of animals merely legume hay and grain from the cereals furnish a most satisfactory combination. When to these vitally important facts we add the great basic one, that the generous and continuous growing of legumes is absolutely essential to the economical maintenance of soil fertility, then, and only then, do we begin to appreciate the importance of this beneficent group of plants in husbandry. In considering the legumes it must be kept in mind that these crops flourish and build up the nitrogen content of the soil only when the proper nodule-forming bacteria are present in the soil. Where these nitrogen-fixing germs are lacking, it is essential that the soil be inoculated by some means.

I. Alfalfa

337. Alfalfa, *Medicago sativa.*—The alfalfa plant is at its best in the great semi-arid plains region covering the western half of the United States, where the alkaline soil is usually rich and deep, with perfect drainage. When amply watered by irrigation and energized by the tropical sun of summer, alfalfa here furnishes from 2 to 5 cuttings each season, yielding a total of from 2 to 5 tons of nutritious hay per acre. In the hot irrigated districts of the Southwest as many as 9 to 12 cuttings have been secured in a single season. Within the humid region, experience is fast locating districts scattered from Louisiana to Maine where this plant, which requires a deep, well-drained soil, rich in lime, may be profitably grown. Alfalfa thrives under irrigation in hot semi-arid climates, but languishes when high temperature is combined with a humid climate, except where soil conditions are unusually favorable. Marked success is obtained with alfalfa on certain soils in the lower Mississippi valley where the annual rainfall exceeds 50 inches, but in general a rainfall of over 40 inches is unfavorable to the crop.[1] Where soil and climate are suitable, this long-time perennial returns good crops for many years without reseeding.

The acreage of alfalfa in the United States doubled during the decade 1899 to 1909, and in the states east of the Mississippi River it increased over eight-fold. The reason for this surprising advance is revealed in the following table, which gives the average yield per acre in 1909 thruout the United States from alfalfa, clover, timothy, and corn:

Returns per acre of alfalfa and other crops

	Yield per acre Lbs.	Dry matter Lbs.	Dig. crude protein Lbs.	Dig. carbohydrates and fat Lbs.	Net energy Therms
Alfalfa hay	5,040	4,632	529	2,143	1,734
Clover hay	2,580	2,185	183	1,080	896
Timothy hay	2,440	2,118	68	1,106	819
Corn (ears and stover)	3,440	2,604	140	2,110	1,762

The table, computed from the average returns for the whole country, shows that alfalfa produced by far the largest yield of dry matter per acre of all forage crops generally available, even 80 per ct. more than corn, the king of forage plants. More striking still is the fact that alfalfa produced almost 3 times as much protein as clover and nearly 4 times as much as corn. It excelled corn in yield of digestible carbohydrates and fat (fat being multiplied by 2.25), tho owing to the high net energy value of the corn grain, the corn plant surpassed alfalfa in yield of net energy.

Even in the eastern states, larger returns are possible from alfalfa than those given above. Voorhees of the New Jersey Station[2] reports a yield of 26.6 tons of green alfalfa forage per acre from 5 cuttings. This contained 11,785 lbs. of dry matter and 2,328 lbs. of crude protein, or as much as is contained in 7.3 tons of wheat bran.

338. Alfalfa for hay.—The recommendation often made, that alfalfa be cut for hay when about one-tenth in bloom, is not a safe rule, especially in the eastern states, where this plant often has but few blossoms. A better guide is to cut for hay as soon as new shoots are well started at the crown of the plant. Cutting late reduces the next crop, for many of these shoots will have grown so long as to be clipped by the mower. By harvesting the crop at this early stage the maximum yield is usually obtained, and the hay is more leafy and palatable, with no undue amount

[1] Piper, Forage Plants and their Culture, p. 310.

[2] Forage Crops.

of fiber. Such hay is suitable for all farm animals except horses, for which late-cut hay is preferable, since, tho less nutritious, it is less "washy." (**506**)

Alfalfa hay is richer than red clover hay in digestible crude protein, but is lower in fat and contains slightly less digestible carbohydrates. Respiration experiments tend to show that clover hay furnishes slightly more net nutrients than alfalfa hay. Appendix Tables I, II, and III show that early-cut alfalfa hay is higher in crude protein and lower in fiber and more digestible than that from more mature plants. In making alfalfa hay it is especially important to guard against the loss of the leaves, which are the most valuable portion of the crop. (**332**) Widtsoe at the Utah Station[3] shows that while the leaves and flowers of alfalfa cut in early bloom make up only about 43 per ct. of the hay, they contain over two-thirds of all the crude protein and nearly three-fourths of all the fat in the crop.

The relative value of the different cuttings of hay will depend on the climatic conditions. Except for horses the finer stemmed, more leafy hay is to be preferred to that which is coarser. Carroll of the Utah Station[4] found no marked difference in the value of first, second, and third crop alfalfa for milk production. (**610**) In certain sections of the West, wild foxtail, or squirrel tail grass, *Hordeum jubatum,* injures the quality of the first cutting on account of its objectionable beards. As this grass makes palatable hay when cut early, the crop may be harvested then or may be ensiled, which will soften the beards.

339. Feeding alfalfa hay.—Owing to the fondness of horses for alfalfa hay their allowance should be restricted lest they gorge themselves thereon. Fed in proper amount alfalfa hay has given satisfaction as the sole roughage even with horses at rapid work. (**506**) The fattening of cattle and sheep in the western states has been revolutionized by the use of alfalfa hay, due to the large and economical gains secured when this nitrogenous roughage is combined with the carbonaceous grains and perhaps silage or wet beet pulp. (**766-8, 857-9**) From the few direct comparisons that have been made of the relative value of alfalfa and red clover hay for fattening animals, we may conclude that these roughages have about equal value for that purpose, and that the real superiority of alfalfa lies not in the greater nutritive value of the hay, but rather in the larger yields. Breeding and stock cattle wintered on this nutritious hay, preferably with corn silage in addition, will more than maintain their weight. Cottrell of the Kansas Station[5] reports that heifers wintered on alfalfa hay alone made an average gain of 1.2 lbs. per head daily, returning 104 lbs. increase for each ton of hay fed. (**797-8**) For breeding ewes alfalfa hay is equally satisfactory. (**884**)

For the dairy cow alfalfa hay is a most excellent feed, since it is rich not only in crude protein but also in mineral matter, especially lime, which is required in large amount in milk production. (**610**) It

[3] Utah Bul. 48. [4] Utah Bul. 126. [5] Kan. Bul. 114.

also has a beneficial laxative effect. The statement is sometimes made that alfalfa hay is fully equal to wheat bran for the milch cow. A comparison of the digestible nutrients and net-energy value of these feeds will show that the hay contains only about nine-tenths as much digestible crude protein as bran, and about 3 times as much fiber. (**218**) Because of this alfalfa hay furnishes only about 70 per ct. as much net energy as bran. It is therefore not surprising that in trials at the New Jersey Station[6] alfalfa hay could not entirely replace bran, cottonseed meal, etc., with cows giving a large flow of milk. The coats of cows fed alfalfa hay in place of all the concentrates were less smooth and glossy than those getting some meal as a part of their ration. When alfalfa furnished as much as 60 per ct. of the crude protein usually supplied in the form of bran, cottonseed meal, etc., there was some shrinkage in milk flow, but a financial saving of over 25 per ct. in the feed cost of producing the milk. (**611-2**)

Alfalfa hay can be largely employed in maintaining shotes and breeding swine during winter. Cottrell[7] states that brood sows wintered on alfalfa hay with no grain farrowed large, healthy litters of pigs in the spring. Even for fattening pigs numerous trials show that a limited amount of alfalfa hay aids in producing cheap gains. (**1010**)

340. Pasturing alfalfa.—Alfalfa is not primarily a pasture plant, for it grows from buds on the crowns instead of by a lengthening of the lower parts of the stems and blades, as with the grasses. Especially in humid regions grazing is apt to injure the stand. Cattle and sheep on alfalfa pasture are, moreover, subject to bloat. Nevertheless, this crop furnishes such nutritious pasture that it is grazed on many farms even in the eastern states. To avoid serious injury to the stand, fields should never be pastured until they have become well established and animals should be kept off when the ground is frozen, soft, or muddy. Heavy stocking of the pasture is decidedly injurious, especially with horses and sheep, which gnaw the plants to the ground. Since certain parts of a field are always more palatable to stock and these are grazed closely while other spots are passed by, Wing[8] advises a combination of pasturing and mowing. The area to be pastured is divided into 3 lots, and after the stock have eaten a considerable part of the crop on the first they are turned onto the second lot, the alfalfa remaining on the first being cut for hay. When the first lot has grown to about the blooming stage it is again grazed. Except where mild winters prevail, alfalfa should be allowed to grow to a height of 6 to 12 inches in the fall for winter protection.

Alfalfa pasture is especially suitable for horses and pigs, which are not subject to bloat. Gramlich of the Nebraska Station[9] found that horses fed hay at noon only and turned on alfalfa pasture at night stood hard farm work as well as others which were dry-fed. For colts

[6] N. J. Bul. 204.
[7] Kan. Bul. 114.
[8] Alfalfa Farming in America, p. 337.
[9] Nebr. Exten. Bul. 28.

and young horses the succulent alfalfa, rich in protein and mineral matter, is especially helpful. (**509**) This pasture is the foundation of cheap pork production on thousands of farms. (**984-5**)

The danger to cattle and sheep from bloat varies greatly with climate and other factors. Tho it is always present in some degree, in such sections as the irrigated districts of the Southwest, but trifling loss is experienced. Sheep are more subject to bloat than cattle. The following methods advocated by Coburn[10] and Wing[11] will aid in avoiding bloat, tho no procedure is absolute insurance against loss: For permanent pasture sow with the alfalfa, bluegrass, brome grass, or some other grass adapted to your conditions. Use upland in preference to lowland for pasture, and have a constant supply of water for the stock. Frosted alfalfa is especially dangerous, but in the late fall after the crop has dried it may be grazed again. Before turning animals on alfalfa for the first time, allow them to fill up on grass pasture, with grain in addition, if they have been accustomed to it. Then in the middle of the forenoon, when they do not care to graze longer, turn them on the alfalfa. Tho some advise allowing the stock to graze only a few minutes the first day and gradually increasing the length of time on the following days, it is probably safer to keep them on the pasture continuously, for they will then never consume undue amounts at one time. Watch the stock closely for the first few days and remove permanently those animals which exhibit symptoms of bloat, for individuals show great differences in their susceptibility to the trouble. The Miller and Lux Co., who graze thousands of cattle on alfalfa in the San Joaquin valley, California,[12] when starting cattle on alfalfa pasture cut part of a field and turn the cattle upon this portion after the alfalfa is half dry. Then after they are well filled they are allowed to eat whatever of the green crop they wish.

341. Alfalfa for soilage.—Alfalfa is one of the most valuable of all soiling crops, owing to the large yields and the fact that under proper management it will furnish rich succulence thruout the entire summer. Considerably more forage may be obtained from a given area as soilage than animals gather by grazing. In a trial with dairy cows by Lyon and Haecker at the Nebraska Station[13] only half as much feed was secured when alfalfa was pastured as when the crop was cut and fed as soilage. Voorhees of the New Jersey Station[14] reports that the first cutting is ready about the last of May or the first of June, with 3 cuttings following at intervals of from 4 to 6 weeks. In certain hot irrigated sections of the West where no satisfactory grass pastures can be provided in summer, dairy cows are often maintained for most of the year mainly on alfalfa, fed as soilage. In the Sacramento valley many herds are fed 30 to 40 lbs. of green alfalfa per head daily with what alfalfa hay they will eat, but no concentrates. The allowance of alfalfa soilage

[10] The Book of Alfalfa, pp. 109-119.
[11] Alfalfa Farming in America, pp. 338-344.
[12] Information to the authors.
[13] Nebr. Bul. 69.
[14] Forage Crops.

may even be increased to 50 lbs., which amount will furnish nearly 2 lbs. of digestible crude protein.[15] Alfalfa alone makes a very narrow ration, the nutritive ratio being 1:4.0 or less. Undoubtedly larger production would be secured were some carbonaceous concentrate added. Whether this would be profitable, however, would depend on the relative price of the feeds. Complaints have been received from practical dairymen that this one-sided ration tends to abortion and other troubles. In Europe where soilage is commonly fed to horses in summer alfalfa is the most popular crop.[16] Whether it will prove profitable to feed alfalfa as soilage rather than to graze it will be determined by the relative cost of land and labor.

342. Alfalfa silage.—In many instances alfalfa is ensiled with entire success, but often poor, vile-smelling silage is produced. The difficulty seems due to the high protein content of the crop compared with the small amount of sugars, from which the acids necessary to preserve the silage may be formed. (**404**) True[17] reports the successful ensiling of alfalfa at the Nevada Station during 4 successive years. If the crop was somewhat dry when put into the silo, water was added to it. Favorable results have been secured when alfalfa has been ensiled with green rye or wheat cut when just past the milk stage, when they are rich in sugars. Esten of the Connecticut (Storrs) Station[18] suggests that the third cutting of alfalfa may be satisfactorily ensiled with green corn or sorghum. Owing to the palatability of good alfalfa hay, whenever the crop can be cured in a satisfactory manner there is little reason for ensiling the crop, especially in view of the fact that either corn or the sorghums are reliable silage crops in nearly all sections of the country. In the West where foxtail, with its troublesome beards, sometimes greatly injures the quality of the first cutting, it may be profitable to ensile the crop. (**338**) Alfalfa should be ensiled just as soon after cutting as possible and should preferably be cut into short lengths so that it may be well packed. When it is impossible to avoid undue curing, it should be ensiled with dew on it or water should be added.

343. Types of alfalfa.—Besides the common alfalfa, which is the type chiefly grown in the United States, various other types are of importance in certain sections. *Turkestan alfalfa* is indistinguishable from ordinary alfalfa in growth. Tho inferior in the humid regions, the consensus of opinion in semi-arid regions is that it is somewhat superior to the common type in drought and cold endurance. *Arabian and Peruvian alfalfa* are rapid growing, tender strains, which have an unusually long growing season. In the irrigated districts of the Southwest these types are valuable. Several strains of *yellow-flowered, sickle,* or *Siberian alfalfa* (*Medicago falcata*), some of which produce rootstocks, have been introduced into the northern plains district. This type is especially hardy and promises to be of value in climates too severe for the common type. The term *variegated alfalfa,* or *sand lucern,* is applied to hybrids of the

[15] N. J. Bul. 148.
[16] Wing, Alfalfa Farming in America, p. 331.
[17] Information to the authors.
[18] Conn. (Storrs) Bul. 70.

common and Siberian types, which are exceptionally drought resistant and hardy.

344. Alfalfa meal and feed.—The manufacture of alfalfa meal (ground alfalfa hay) and various feeds containing more or less of this material has increased rapidly of late. Alfalfa meal varies in fineness from a product nearly as fine as corn meal to a coarsely chopped or shredded material, containing pieces half an inch in length. Compared with hay the meal is easier to transport to distant markets, there is somewhat less waste in feeding it, and for animals having poor teeth, or horses worked long hours, the grinding is undoubtedly beneficial. (**507**) The bulky meal is also helpful in diluting heavy concentrates, which, if carelessly fed, may cause digestive disturbances. For these reasons alfalfa meal has a legitimate field. However, grinding ever so finely will not transform a roughage into a concentrate. As shown elsewhere (**424**), with animals having good teeth and ample time to masticate their food, grinding hay does not increase its digestibility. Owing to the great palatability of well-cured alfalfa hay but little is refused when it is fed long. Unfortunately, it is impossible to determine without chemical or microscopic analysis whether alfalfa meal has been made from nutritious, leafy, early-cut hay or from over-ripe, stemmy material. Hence the meal should be purchased on guarantee of composition, special attention being paid to the fiber content, which in first-class meal should not be higher than in good quality hay, or about 30 per ct.

From 4 trials at the Colorado Station[19] Morton concludes that for fattening lambs the value of ordinary alfalfa hay may be increased 15 to 25 per ct. by grinding, but that with hay of good quality such preparation will not pay. (**835**) McCampbell of the Kansas Station[20] found that alfalfa meal, fed dry, irritated the nostrils of horses and that they preferred long hay to the meal when wet. He concludes that alfalfa meal is not a desirable or an economical feed for horses when good alfalfa hay is available. (**507**) In view of the fact that the market price of alfalfa meal is often as high or higher than wheat bran, it is important to note that in trials at each of 3 stations substituting good quality alfalfa meal for an equal weight of bran lessened the production of dairy cows. (**613**) Ordinarily the stockman can produce roughage more economically on his farm than he can purchase it in commercial feeds. In case he desires to mix hay with heavy concentrates the material may readily be cut sufficiently fine in a silage cutter. Unless good alfalfa meal sells at an appreciably lower price than wheat bran its purchase can not be recommended.

Molasses, either beet or cane, is now mixed with alfalfa meal, the product being sold as "alfalmo" or under other names. The mixture is well-liked by stock, but its economy as a feed must be determined by comparing the composition and price with those of other feeds. Many mixed feeds, discussed in Chapter XI (**285**), contain more or less alfalfa meal.

[19] Colo. Bul. 187.
[20] Kan. Bul. 186.

II. Red Clover

345. Medium red clover, ***Trifolium pratense.***—This legume, commonly known as red clover, is the most important legume in the humid sections of the northern two-thirds of the United States, where, grown in rotation with corn and the cereals, it so helpfully serves for pasture and hay production and for the maintenance of soil fertility. Clover is chiefly seeded in combination with timothy, 19,542,000 acres of mixed clover and timothy being grown for hay in the United States in 1909, compared with only 2,443,000 acres of clover alone. Red clover does best on well-drained soils rich in lime, being intolerant of a water-logged or acid soil. A short-lived perennial, but few plants live over 3 years, and the crop is usually treated as a biennial.

Thruout the clover-growing districts red clover generally yields a heavy first crop of hay, with a second cutting which is usually much lighter and which is often allowed to mature for seed. In the southern states, where it does not thrive during the heat of summer, red clover is sometimes grown as a winter annual, the first crop being cut in the spring and the second in early summer. At the northern limits of its culture but one cutting is produced. The average yield of clover hay per acre, according to the census of 1910, was 1.29 tons, but under favorable conditions much higher returns are secured, the yield in 2 cuttings ranging from 2 to 4 tons or even more per acre.

On all stock farms in the eastern United States there should be a well-planned rotation of crops, such as corn, followed by either wheat, oats, or barley, and this in turn by a legume, preferably red, alsike, or mammoth clover, grown either alone or with the grasses, some of the fields being grazed by the stock.

Under such a rotation, when proper use is made of the farm manure, reinforced by phosphate and potash fertilizers when necessary, the humus and fertility of the soil on the whole farm is maintained or even increased, the weeds are held in check, and the maximum yield of crops is economically produced on all the fields. Because alfalfa fields are usually difficult to establish and should be maintained for many years, the alfalfa plant does not particularly favor a short rotation of crops. In their eagerness to grow alfalfa, ambitious farmers in the East are apt to neglect the clovers, which are so vitally helpful in maintaining fertility of the whole farm in short-time crop rotations. In many cases the growing of red or mammoth clover has been abandoned on account of failure to secure stands. Such "clover sickness" of the soil may be due to certain diseases, but in most cases it means that lime and phosphate, and possibly potash are needed. Farmers who willingly prepare fields thoroly for alfalfa often fail to exercise reasonable care to get good stands of clover.

346. Development of nutrients.—Immature clover, like all young plants, is exceedingly watery. At the Wisconsin Station[21] Woll found

[21] Wis. Rpt. 1889.

but 8.2 per ct. dry matter in green clover cut long before it had reached the proper condition for making hay. Such clover contained more water than skim milk. This explains why clover when cut too early is such unsatisfactory soilage; the animals cannot then consume enough to secure the nourishment they require.

Hunt of the Illinois Station[22] has arranged the results of studies of the medium red clover plant, made by himself and Jordan of the Pennsylvania Station, to show the yield per acre at various stages of growth.

Yield and nutrients in an acre of medium red clover

Stage of growth when cut	Yield of hay per acre	Ash	Crude protein	Carbohydrates Fiber	Carbohydrates N-free extract	Fat
Illinois, Hunt	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Full bloom	3,600	217	400	660	1,052	197
Heads three-fourths dead	3,260	196	379	672	1,024	156
Pennsylvania, Jordan						
Heads in bloom	4,210	260	539	1,033	1,731	116
Some heads dead	4,141	226	469	1,248	1,379	106
Heads all dead	3,915	208	421	1,260	1,378	94

The table shows that when cut at full bloom the clover crop yielded the largest amount of hay per acre, and also contained more ash, crude protein, nitrogen-free extract, and fat. The fiber, or woody matter, which is the least valuable portion of the plant, was the only nutrient which increased after full bloom. The loss of other nutrients after blooming was due to the withering and dropping of the lower leaves and probably to a leaching of soluble nutrients by rains. This shrinkage of nutrients as clover matures is similar to that in the smaller grasses (**313**), and is in marked contrast to the continued storage of nutrients up to full ripening in Indian corn. (**23**)

The table clearly points to full bloom as theoretically the best date for cutting clover hay. Practical experience, however, places the time somewhat later, or when about one-third of the blossom heads have turned brown. This is because at any earlier date the plant is so soft and sappy that only with difficulty can it be cured into good hay. Delaying until all the heads are dead makes haying still easier, but means poor, woody, unpalatable hay.

347. Clover for hay.—Well-cured clover hay, bright and with leaves intact, is a most excellent roughage for all farm stock. Tho dusty clover hay is to be avoided for feeding horses, that of good quality is successfully and economically used with both farm and city horses. (**505**) Mixed clover and timothy hay is preferred by many to clear clover hay for horse feeding since it usually is more free from dust.

No investigations of the experiment stations in animal husbandry have been more helpful than those showing the great value of the legumes, including clover hay, for fattening cattle and sheep. By adding clover hay to the ration the grain requirement can be materially reduced and the fattening period shortened—both matters of great im-

[22] Ill. Bul. 5.

portance in these days of high-priced concentrates. (**764, 857-9**) For the cow, clover hay is unexcelled as a roughage, unless by alfalfa. Not only is it palatable and much relished, but it is high in protein and lime. Where well-cured clover hay furnishes one-half or more of the roughage, the dairyman is able to cut the allowance of concentrates and materially reduce the cost of the ration. (**614**) This roughage has the same high place for feeding breeding ewes, wintering cattle, and especially for young animals. (**787, 798-9, 692**) Early-cut clover hay ranks next to alfalfa for swine, being especially valuable for breeding stock. (**1011**)

348. Clover for pasture, soilage, and silage.—Clover pasture is helpful and important for all farm animals. For pigs it furnishes about sufficient food for maintenance, so that all the grain fed goes for gain. Clover-pastured pigs are healthy and have good bone and constitution—points of special importance with breeding stock. (**986**) Tho there is somewhat less danger from bloat with clover than alfalfa, cattle and sheep should not be turned on clover pasture for the first time while hungry or before the dew has risen. As a preventive, dry forage, such as hay or straw, should be placed in feed racks in the pasture. To these cattle and sheep will resort instinctively when bloat threatens.

Clover is particularly valuable for soilage, ranking next to alfalfa among the legumes available for that purpose. By cutting clover early, it at once starts growth again if the weather is favorable, and will furnish three or four cuttings annually. In some cases clover has made fair silage, but so many failures have occurred that this plant cannot be recommended for such purpose except where weather conditions prevent its being properly cured into hay. The same precautions should then be taken as with alfalfa for silage. (**633**)

III. Other Clovers and Leguminous Forage Plants

349. Mammoth clover, *Trifolium medium.*—The distinctive characteristics of mammoth clover are its rank growth, coarse stems, and blooming 2 or 3 weeks later than the medium variety. It usually lives 3 years or more and thrives better on poor or sandy soil than does medium red clover. Since it yields but a single cutting during the season, this clover is frequently pastured for several weeks in the early spring. After the stock is removed the plants shoot up and are soon ready for the mower. Owing to its coarser growth the hay is more difficult to cure and somewhat less palatable than red clover. Wallace[23] recommends that for pasture medium and mammoth clover seed be sown in equal proportions, together with grasses, holding that since mammoth clover blooms later there is more nearly a succession of good forage than is possible with only one variety.

350. Alsike clover, *Trifolium hybridum.*—This variety of clover, once supposed to be a cross between red clover and white clover, has weak

[23] Clover Culture.

stems which fall to the ground unless supported by attendant grasses. Alsike flourishes on land too acid or too wet for other clovers, and is a hardier, longer-lived plant, enduring 4 to 6 years in good soil. As it will grow readily on "clover-sick" soil, it has replaced red clover on many fields during recent years. Well-made alsike hay is fine-stemmed and ranks among the best, being eaten with but little waste.

351. White clover, *Trifolium repens.*—This creeping perennial has the widest range of any of the clovers, thriving in almost any soil from Canada nearly to the Gulf of Mexico, if moisture is ample. In the North it is an important plant in mixed pastures, forming a dense mat of herbage and furnishing feed thruout the growing season. In the South it nearly disappears in summer, but reappears in the fall furnishing winter pasturage and thus combines well with Bermuda grass. (**320**) Owing to its low, creeping growth it does not yield hay.

352. Sweet clover.—White sweet clover, *Melilotus alba,* also known as melilot and Bokhara clover, is a biennial which is widely distributed along roadsides and in waste places over southern Canada and a large part of the United States, thriving best on soils rich in lime. It will grow on soil so poorly drained or so worn and low in humus that alfalfa or red clover will not live. Increasing experience shows that where these more valuable legumes do not thrive, sweet clover, which was once viewed as a weed, is of considerable value. Thousands of acres of depleted, gullied land in Kentucky and Tennessee are being restored to fertility by this legume. In the West it may be grown on hard adobe soils, which it mellows with its deep root system. The plant may also be utilized for pasture, hay, and soilage, and has occasionally been ensiled. At first animals usually refuse sweet clover, for all parts of the plant contain *cumarin,* a bitter compound with a vanilla-like odor. In spring the herbage is less bitter and animals of all classes can generally then be taught to eat it. After becoming accustomed to the taste they are said sometimes to prefer sweet clover to other legumes or the grasses. In certain districts where the plants seem unusually high in cumarin it is reported that animals cannot be induced to eat them. When the clover is cured as hay a large part of the cumarin is volatilized, the hay thus being less bitter than the green plants.

Sweet clover seed should be thickly sown so that the stems will not grow coarse, and the crop should be cut when the first blossoms appear, or even before, since after this stage they rapidly grow woody. The first season 1 cutting and the second 2 of hay can be secured in the North, and often 3 in the South. The crop should be cut about 6 inches from the ground, for the new shoots grow out not from the crown, as in alfalfa, but from the stems. Lloyd of the Ohio Station[24] states that farmers report good results from feeding sweet clover to horses and cattle. (**769**) Wilson[25] found the hay satisfactory for lambs at the South Dakota Station, and Evvard[26] obtained good results with sweet clover as a hog pasture at the Iowa Station, but alfalfa or red clover are

[24] Ohio Bul. 244. [25] S. D. Bul. 143. [26] Iowa Bul. 136.

probably preferable where they produce good crops. Sweet clover rarely causes bloat. The plants should be grazed closely, as otherwise they become woody. A yellow-flowered sweet clover, *Melilotus officinalis*, 2 weeks earlier and somewhat smaller in growth than the white sweet clover, has been quite widely introduced in the United States.

353. Crimson clover, *Trifolium incarnatum*.—This annual clover, adapted to mild climates, is grown chiefly in the Atlantic seaboard states from New Jersey to South Carolina. Here it is treated as a winter annual, being sown in the late summer or early fall, blossoming the following spring, and dying by early summer. Crimson clover has proved vastly helpful to the agriculture of these states, where it is used mainly as green manure and as a winter cover crop. It is extensively used for pasture and hay, and to a more limited extent for soilage. This clover is suited to a wide range of soils, succeeding on both sandy and clay land if well drained. Duggar of the Alabama,[27] and Williams of the North Carolina Station[28] believe that of all the clovers it has the widest adaptability to southern conditions. An especially valuable feature is that the crop may be harvested or turned under as green manure early enough in the spring to permit the raising of other crops the same year. The climate of the humid Pacific coast section is well adapted to crimson-clover culture.

When grown for hay it is important that crimson clover be cut by the time the flowers at the base of the most advanced heads have faded, even tho the weather be unsettled for hay-making. When cutting is longer delayed, the minute barbed hairs of the blossom heads and stems become hard and wiry. If hay from such over-ripe clover is fed to horses or mules these hairs sometimes mat together in the digestive tract, forming felt-like masses which may grow to the size of baseballs and finally plug the intestines, causing death. When it is necessary to feed over-ripe hay to horses or mules, which are usually the only animals affected, to reduce the danger it should be given with other roughage, preferably with succulent feeds, or else wet thoroly 12 hours before feeding. Grantham of the Delaware Station[29] found that of 108 growers over three-fourths considered crimson-clover hay as good or better than that from red clover or cowpeas. According to Piper[30] yields of hay from good stands average about 1.25 tons per acre. **(615)** During a short season in the spring before it matures, crimson clover furnishes valuable pasturage or soilage in advance of grass or other clovers, and in warm sections it may be utilized as late fall or winter pasture.

354. Bur clovers.—The *southern* or *spotted bur clover (Medicago arabica)* and *California* or *toothed bur clover (M. hispida)* are winter annuals that furnish valuable pasturage in mild regions. The former, which is the hardier, is found chiefly in the southern states, and the latter in California and Texas. They are admirable supplements to

[27] Ala. Bul. 147. [28] N. C. Cir. 7. [29] Del. Bul. 89. [30] Forage Plants, p. 432.

Bermuda pasture, furnishing feed when that grass is resting and reseeding unless grazed too closely. (**320**) Even on land where summer cultivated crops are grown, bur clover, if once sown, volunteers in the fall. Cauthen of the Alabama Station[31] states that tho not commonly so used it may be seeded for hay with fall grain.

355. The common field-pea vine.—The common field pea, *Pisum sativum,* var. *arvense,* the use of which as a grain crop has already been discussed (**261**), is grown in Canada and the northern states to some extent for forage. A combination of peas and oats, if cut early, makes nutritious hay, well liked by all classes of stock and also makes silage of good quality. The combination is frequently sown as a spring soiling crop, especially for dairy cows, or as pasturage, chiefly for swine. In some of the irrigated valleys of the Rocky Mountain region field peas, usually with a small quantity of oats or barley, are sown extensively and grazed when nearly mature by sheep and pigs. (**860, 988**) In the grain which the field pea furnishes and the hay and silage which it is possible to secure from it, the stockman located far north has a fair compensation for the corn crop which he cannot grow.

356. Pea-cannery refuse.—Formerly the bruised pea vines and empty pods from the pea canneries were used only for manure. The value of this rich by-product for stock-feeding has now been abundantly demonstrated, and it is usually preserved in silos or in large stacks, where the decaying exterior preserves the mass within. The silage has a strong odor but is relished by all farm animals, especially dairy cows, fattening cattle, and sheep. (**870**) By spreading cannery waste out thinly on a plat where the grass is short, it may be cured into hay worth, according to Crosby,[32] 20 per ct. more than clover hay, but this involves more labor than placing it in the silo.

357. Cowpea, *Vigna sinensis.*—This hot weather annual is the most important legume in the cotton-belt, furnishing grain for humans and animals (**262**), tho chiefly grown for forage and green manure. Its especial value lies in the fact that it will grow on all types of soil and with but little attention, increasing the fertility of the land and furnishing rich hay, pasturage, soilage, and silage. This vine-like plant does not mature in a definite time, but continues to bear pods and put forth new leaves during a long period. Sown at corn planting or later, early varieties mature the first pods in 70 to 90 days. The crop may be then cut for hay, or the harvesting considerably delayed without loss. Cowpeas yield from 1 to 3 tons of excellent hay per acre, which is equal to red clover or alfalfa in value and is an excellent roughage for horses, cattle, and sheep. (**508, 769, 859**) When cowpea hay is fed to dairy cows or fattening steers the allowance of concentrates may be reduced to one-half the amount needed when a carbonaceous roughage, such as corn stover or hay from the grasses, is fed. (**616**) Because of the succulent leaves and thick stems the cowpea is difficult to cure. To prevent

[31] Ala. Bul. 165.

[32] U. S. Dept. Agr., Bur. Plant Indus., Cir. 45.

loss of the leaves the crop should be cured in cocks built with devices which permit air circulation. (333)

To support the vines cowpeas are often broadcasted or drilled with sorghum, soybeans, millet, or Johnson grass, and Piper[33] suggests that the new Sudan grass should prove excellent for this purpose, as it matures at the right time and is readily cured. Cowpeas are extensively planted with corn or sorghum, when some cowpea seed is often picked by hand and the remainder of the crop, corn and all, pastured, furnishing economical feed for cattle, sheep, or pigs. (**770, 872, 990**) The combination crop makes palatable, protein-rich silage that should be more extensively used. Thru the greater utilization of cowpeas and other legumes the live-stock industry of the South may be enormously increased.

358. Soybean, *Glycine hispida.*—Soybeans are for the most part bushy plants with no tendency to vine, and which, unlike cowpeas, die after the crop of pods has been matured. (**256**) They thrive in the same climate as corn, maturing sufficiently for hay in northern sections where-ever corn may be grown for silage. Soybeans are better adapted to the northern part of the corn belt than cowpeas, which require a longer growing season and are injured by slight frosts. They are also more drought-resistant than cowpeas and hence well suited to light soils, tho they will not thrive on such poor land as do cowpeas. The fondness of rabbits for the plants is a serious drawback in the plains district. The soybean crop should be cut for hay when the pods are well formed but before the leaves begin to turn yellow, for soon after this the stems become woody and the leaves easily drop off. The crop yields from 1 to 3 tons per acre of hay equal to cowpea or alfalfa hay in feeding value. (**617**) Soybeans alone make rank smelling silage, but 1 ton of soybeans ensiled with 3 to 4 tons of corn or sorghum makes a satisfactory product. For this purpose the soybeans and corn or sorghum may be mixed as ensiled or they may be grown together. In the South soybeans alone or soybeans and corn are often grazed by hogs. When designed for pasture the beans should be planted in rows to lessen the loss by tramping, and the hogs should not be turned in until the pods are nearly mature. (**989**) In the northern states the chief value of soybeans is for sandy land or as a catch crop when clover or other crops fail. Moore and Delwiche of the Wisconsin Station[34] report that soybeans planted in June on jack-pine sand where sugar beets had failed produced 2 tons of hay per acre. Evvard of the Iowa Station[35] found soybeans or cowpeas surpassed for hog pasture by rape, clover, and alfalfa on soil where the latter crops flourished.

359. Vetch.—Only the *hairy vetch* (*Vicia villosa*), also called sand or Russian vetch, and the *common vetch* (*V. sativa*), also known as smooth or Oregon vetch, are important in the United States. Both are ordinarily annuals, tho the hairy vetch especially may live for more

[33] Forage Plants, p. 505. [34] Wis. Bul. 236. [35] Iowa Bul. 136.

than a year. Being cool-weather plants, they are usually fall-sown in mild climates, but a spring strain of the common vetch is sometimes grown. While common vetch is killed by zero temperatures, hairy vetch usually endures the winter in the northern states if well established in the fall. Hairy vetch may be grown on poorer soil than its relative, is adapted to a wider range than crimson clover, and is markedly drought resistant. It is chiefly grown for hay, being usually sown with the cereals to support the weak vines, which clamber from 4 to 10 feet in a tangled mass. Harvested when the pods are full grown, a palatable hay is secured. According to Piper[36] the yield from vetch grown alone ranges from 1.5 to 2.5 tons or more of hay per acre. (**619**)

In the South and in western Washington and Oregon where the winters are not severe, common vetch is preferred for soil rich enough for its culture, since the seed is cheaper and the vines grow less tangled. Piper places the yield of hay at 2.5 tons in the latter district and slightly less in the southern states. Smith of the United States Department of Agriculture[37] reports that at Atlanta, Ga., vetch and oat hay is popular with liverymen, selling on a par with cowpea hay. Besides furnishing hay, the vetches afford excellent pasturage for cattle, sheep, and swine. Smith reports the successful use of vetch silage for a dairy herd.

360. Lespedeza, *Lespedeza striata.—Japan clover,* commonly called *lespedeza* in the South, is a summer annual which has now spread over most of the territory from central New Jersey westward to central Kansas and south to the Gulf. Here, even on the poorest soils, it appears spontaneously as a common constituent of mixed pastures, and unless closely grazed reseeds itself from year to year. On the poorer sands and clays of the cotton belt lespedeza is perhaps the most valuable pasture plant, adding nitrogen to the soil, binding it together, preventing washing, and furnishing pasturage well-liked by all stock. This legume has not been known to cause bloat. Only on rich soil does it grow tall enough for hay. The crop is easily cured and in extreme cases yields 3 tons of hay per acre, which according to Duggar of the Alabama Station[38] is equal to alfalfa. (**497**)

361. Velvet bean, *Stizolobium deeringianum.*—The tropical velvet-bean plant flourishes south of a line drawn from Savannah, Georgia, to Austin, Texas. The vines, which run on the ground from 15 to 75 feet, are difficult to cure into hay, and are mostly used for grazing. Scott of the Florida Station[39] reports a yield of 20 to 30 bushels of 60 lbs. of shelled beans per acre. He states that 1.5 tons of beans in the pod are equal to 1 ton of cottonseed meal for milk production and can be produced at 30 per ct. of the cost of the meal. (**604**) Scott found that the fat of pigs fed exclusively on velvet beans has a dark, dirty appearance and disagreeable odor and taste, which may probably be avoided by feeding a limited quantity of beans with corn, cassava, etc.

[36] Forage Plants, p. 472.
[37] U. S. Dept. Agr., Farmers' Bul. 529.
[38] Wing, Meadows and Pastures, p. 354.
[39] Fla. Bul. 114.

The charge that velvet beans cause abortion among cattle and swine and blind staggers with horses is substantially without foundation. Horses fed exclusively on velvet-bean hay may suffer from kidney trouble, but all danger may be averted by feeding equal parts of velvet-bean and crab-grass hay. Tracy[40] reports 20 acres of velvet beans in Florida furnishing half the daily grazing for 30 cows during 27 days in winter, after which 10 tons of pod beans were harvested. Eighty acres of velvet beans in southern Georgia furnished grazing for 100 head of cattle 4 months. Seventy days' grazing on velvet-bean pasture was sufficient to put steers in marketable condition. (**760**)

362. Peanut, *Arachis hypogaea.*—Peanuts are grown chiefly for the under-ground nuts (**258**), tho the entire plant is sometimes cured into a nutritious hay. According to Piper,[41] as a hay plant the peanut cannot compete with the soybean or the cowpea, but the plant is of importance as a pasture crop for hogs, which root out the nuts. Hogs finished solely on peanuts yield a soft pork, but this may be largely avoided by feeding corn or other feeds. (**1005**) Since the nuts will not long remain in the ground without sprouting, the crop must be pastured soon after maturity. When peanuts are grown for the seeds, the straw is used for stock feeding, the yield ranging from 0.75 to 1.5 tons or more per acre.

363. Beggar weed, *Desmodium tortuosum.*—This annual legume, which has rather woody stalks 3 to 10 feet high bearing abundant leafage, is used for green forage and hay production in the sub-tropical regions of our country. Garrison of the South Carolina Station[42] reports a yield of over 11.5 tons of green and 2.25 tons of dry forage from 1 acre. Smith[43] states that on rich land yields of from 4 to 6 tons of hay are not unusual. The hay ranges between clover and alfalfa in protein content and is relished by stock.

364. Miscellaneous legumes.—The *Tangier pea* (*Lathyrus tingitanus*), which is somewhat similar to the common sweet pea, but more vigorous in growth, has given promising results as a hay and green manure crop in the southern states and western Oregon.[44] *Serradella* (*Ornithopus sativus*), cultivated to a considerable extent in Europe on poor sandy land, has thus far attained no importance in the United States. As it will grow on soil too acid for other legumes it may be found useful on acid sands in the northern states. The *moth bean* (*Phaseolus aconitifolius*), a native of India, is in many ways superior to the cowpea in northern Texas, according to Conner[45] being more drought resistant and curing more readily. The *hyacinth bean* or *bonavist* (*Dolichos lablab*), an annual resembling the cowpea but more viny, is often grown as an ornamental. It is of no especial promise as a forage crop except in

[40] U. S. Dept. Agr., Farmers' Bul. 300.
[41] Forage Plants, p. 547.
[42] S. C. Bul. 123.
[43] U. S. Dept. Agr., Yearbook, 1897.
[44] Wash. Bul. 2., Spec. Series.
[45] Tex. Bul. 103.

the plains region of Texas, where it is apparently somewhat more drought resistant than the cowpea.[46]

The *Kudzu vine* (*Pueraria thunbergiana*) is a rapidly growing annual vine, often grown as an ornamental in the South, where it reaches a length of 60 feet or more. Recent trials show it to be of considerable promise as a perennial forage crop for the Gulf region. Under field conditions the prostrate branches root at the joints and send up twining shoots 2 to 4 feet high, which may be readily cut with a mower. According to Piper,[47] in northern Florida 3 cuttings of hay a season have been obtained, the yield ranging from lower than velvet beans to as high as 10 tons per acre.

[46] Tex. Rpt. 1912.

[47] Forage Plants, p. 564.

CHAPTER XV

ROOTS, TUBERS, AND MISCELLANEOUS FORAGES

I. Roots and Tubers

In northern Europe and in eastern Canada root crops are extensively grown for stock, but in this country such use has never assumed importance. Indeed, in 1909 over 5000 acres of corn were raised in the United States for each acre of roots grown for live stock feeding. Having cool summers, northern Europe is well suited to the growth of roots but not to the culture of corn, while in most parts of our country, with the hot summers, this imperial grain and forage plant thrives. As shown later in this chapter, where corn flourishes it furnishes a palatable, succulent feed at less cost than do roots. Hence, it is reasonable to expect that in the United States the culture of roots for forage will increase only in districts having summers so cool that these crops give better returns than corn, and on farms in the corn belt where too few animals are kept to use corn silage economically, or where roots serve as a relish for show animals and dairy cows on official test.

365. Use and value of roots.—Roots should be regarded not as roughages, but as watered concentrates, high in available energy for the dry matter they contain. (**22**) All are low in crude protein compared to their content of carbohydrates. The studies of Friis[1] in Denmark and Wing and Savage at the New York (Cornell) Station[2] show that for the dairy cow a pound of dry matter in roots has the same feeding value as a pound of dry matter in grain, such as corn, wheat, or barley. (**637**) Wing and Savage found that mangels could replace half the grain ordinarily fed in a ration of grain, mixed hay, and silage without reducing the yield of milk or butter, and that with grain at $30 per ton, mangels were an economical substitute when they could be grown and stored for $4 per ton.

Since nearly 90 per ct. of the dry matter in roots and only 66 per ct. of that in well-matured corn silage is digestible, one would expect the dry matter of roots to have somewhat the higher value. However, in the majority of the trials in which this question has been studied with the dairy cow, just as much milk was produced from 100 lbs. of dry matter in the silage ration as in the ration containing roots. (**638**)

In addition to the nutrients they furnish, roots and other succulent feeds have a beneficial tonic effect upon animals, and are especially helpful in keeping breeding cattle, sheep, or swine in thrifty condition. Many successful stockmen recommend roots highly for animals being

[1] Expt. Sta. Rec., 14, 1903, p. 801. [2] N. Y. (Cornell) Bul. 268.

fitted for exhibitions and for dairy cows crowded to maximum production on official tests. At the Michigan Station Shaw[3] and Norton found that when roots were added to a well-balanced ration for dairy cows containing good corn silage the yield of butter fat was increased 5.8 per ct. Yet this increase was not sufficient to offset the greater cost of the ration containing the roots. (**640**)

In this country the daily allowance of roots per 1,000 lbs. live weight is usually 25 to 50 lbs. or less. Thruout Great Britain fattening cattle and sheep are often fed 100 lbs., or even more, per 1,000 lbs. live weight daily with satisfactory results, and sheep are sometimes fattened on concentrates and roots alone. This practice can not be generally recommended, for better results are secured when some dry roughage is fed. Roots are usually chopped or sliced before feeding, and the cut roots are often put into the feed box and meal sprinkled over them. In feeding cattle in Canada and England, roots are quite commonly pulped and spread in layers several inches thick, alternating with other layers of cut or chaffed hay or straw. After being shoveled over, the mass is allowed to stand several hours before feeding, to moisten and soften the chaffed straw or hay. In this manner great quantities of straw may be successfully utilized. (**784, 786, 865**) For winter feeding in the northern states roots must be stored in well-ventilated pits or cellars, but in mild climates they may remain in the field until fed. In Great Britain sheep are often grazed on root crops, saving the labor of harvesting.

366. Roots vs. corn silage.—The most extensive of several trials in which the yields of roots and silage corn have been compared are summarized in the following table:

Yield of fresh and dry matter per acre of roots and fodder corn

Station	Mangels		Sugar beets		Rutabagas		Fodder corn	
	Green weight	Dry matter	Green weight	Dry matter	Green weight	Dry matter	Green weight	Dry matter
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Maine*	15,375	1,613	17,645	2,590	31,695	3,415	39,645	5,580
Penn.†	38,273	4,554	25,591	4,683	.....	....	18,332	6,763
Ontario,‡ 5–8 yrs	47,480	4,440	29,760	4,890	39,260	4,260	38,320	8,050
Average	33,713	3,536	24,332	4,054	35,478	3,838	32,099	6,798

*Woll, Book on Silage. †Penn. Rpt. 1898. ‡Ontario Dept. Agr., Bul. 228.

On the average, the corn crop contained 92 per ct. more dry matter than mangels, 68 per ct. more than sugar beets, and 77 per ct. more than rutabagas. At the Ohio Station[4] Thorne found that to grow and harvest an acre of beets yielding 15.75 tons and containing 3,000 lbs. of dry matter cost more than an acre of corn yielding 57 bushels of grain and containing 6,000 lbs., or twice as much, dry matter. In trials covering

[3] Mich. Bul. 240. [4] Ohio Rpt. 1893.

4 years at the New York (Cornell) Station[5] Minns found the cost of growing and ensiling silage corn about the same per ton as that for growing and harvesting mangels. However, owing to their watery nature 100 lbs. of dry matter in mangels cost over twice as much as in corn silage. These findings show that where corn thrives, corn silage will furnish dry matter at one-half the cost of roots or less. This is largely because root crops require more careful and thoro preparation of the soil and far more hand labor in cultivation, harvesting, and storage than does corn.

367. Yields of various root crops.—The most extensive comparisons of the yields of various root crops are those reported by the New York (Cornell) Station[6] from 5-year tests and by the Ontario Agricultural College[7] from trials covering 5 to 15 years, which are summarized in the following table. The yields from kohlrabi, cabbage, rape, and kale, which are sometimes included loosely under the term "root crops" are also given, along with the return from a 200-bushel crop of potatoes.

Yield and dry matter per acre in various root crops

	New York (Cornell) Station		Ontario Agr. College	
	Green wt. Tons	Dry matter Lbs.	Green wt. Tons	Dry matter Lbs.
Mangels	39.7	8,400	23.7	4,440
Sugar mangels	28.1	6,400	24.0	5,460
Sugar beets	28.3	8,000	14.9	4,890
Rutabagas (swedes)	26.3	5,000	19.6	4,260
Hybrid turnips	27.1	5,200	....	....
Turnips	16.8	3,600	27.2	5,160
Carrots	18.5	4,400	27.5	6,460
Parsnips	8.3	3,800	8.3	2,750
Kohlrabi	23.4	4,600	15.8	2,819
Cabbage	36.4	4,600	23.1	4,102
Dwarf Essex rape	....	....	17.2	5,758
Thousand-headed kale	....	....	17.7	4,000
Potatoes (200 bushels)	6.0	2,540	6.0	2,540

As is shown in the table, the rank of these various crops varies widely in different sections, depending on the climatic and soil conditions.

368. The mangel, ***Beta vulgaris,*** **var.**—Tho the mangel, or mangel wurzel, is the most watery of roots, it returns a large amount of dry matter per acre because of its enormous yield. The dry matter content of mangels averages 9.4 per ct. and that of the half-sugar mangels, which are crosses between the mangel and the sugar beet, is somewhat higher. Because it stands well out of the ground, the mangel is easily cultivated and harvested, and furthermore it keeps better in winter than does the sugar beet. Mangels should not be fed until they have been stored for a few weeks, as the freshly-harvested roots may cause scours. Mangels are useful for all farm animals, except possibly the horse. (**637-8, 784, 864**) Fed to rams or wethers for long periods, both

[5] N. Y. (Cornell) Bul. 317.
[6] Piper, Forage Plants and their Culture, p. 587.
[7] Ontario Dept. of Agr., Bul. 228.

mangels and sugar beets tend to produce dangerous calculi, or stones, in the urinary organs.

369. Sugar beets, *Beta vulgaris,* var.—This root has been marvelously developed for the single purpose of producing sugar, some strains now yielding 16 per ct. or more. The sugar beet demands more care in cultivation than the mangel and more labor in harvesting, as it sets deep in the ground. Sugar beets are esteemed by many dairymen as succulence for cows under test. If liberally fed, this root may induce scouring because of its high sugar content. Farmers patronizing sugar factories should utilize cull beets as well as the tops. Beet tops and leaves may be fed fresh or ensiled. Care must be taken when stock is turned on beet fields to forage, as decaying beet tops may poison the animals. According to Morton of the Colorado Station,[8] tho the tops keep better if cut, they may be ensiled whole if the mass is well packed. At the Wisconsin Station[9] Humphrey found that beet tops make good silage when run thru the silage cutter along with an equal weight of dry corn fodder, sufficient water being added so that the mass will pack well.

370. Rutabaga, *Brassica campestris.*—The rutabaga, or swede, ranks next to the mangel in ease of cultivation and harvesting. Sheep prefer it to all other roots. Like other turnips, the rutabaga may taint the milk of cows, and for this reason should be fed immediately after milking. This root is of vast importance to the stock interests of Great Britain and is likewise a favorite in Canada, where it is extensively grown. (**511**)

371. Turnip, *Brassica rapa.*—Turnips are more watery than rutabagas and do not keep so well. Hybrid turnips, crosses between the turnip and the rutabaga, keep better than ordinary turnips. Maturing early, turnips are used chiefly for early fall feeding. Sown as a catch crop, large yields are often secured without cultivation. Tho used mainly for sheep, they can also be fed to cattle.

372. Carrot, *Daucus carota.*—Under favorable conditions the stock carrot gives heavy yields. This root is relished by horses of all ages and conditions, but should not be fed in large amount to hard-worked or driving horses. (**511**) Carrots also serve well for other stock, especially dairy cows. Hills of the Vermont Station[10] writes: "Carrots far surpassed beets in feeding value."

373. Parsnip, *Pastinaca sativa.*—The parsnip is the favorite root with dairy farmers on the islands of Jersey and Guernsey. It contains about as much dry matter as the sugar beet, but because the yield in this country is relatively low and the root difficult to harvest, it is little grown. (**511**)

374. Potato, *Solanum tuberosum.*—In Europe heavy-yielding varieties of large-sized potatoes are extensively grown for stock, but in this country potatoes are only fed when low in price or too small for market. Knowing their feeding value, the farmer is in position to utilize the

[8] Breeder's Gaz., 65, 1914, p. 115. [9] Wis. Bul. 228. [10] Vt. Rpt. 1907.

crop wisely, for feeding his live stock, rather than to force it on a profitless market. Potatoes are chiefly employed for swine feeding (**1001**), but may be fed in limited amounts to cattle, sheep, and horses in partial substitution for grain. For pigs the tubers should be boiled or steamed, and mixed with meal. The heavy feeding of raw potatoes is not advisable, as it induces scouring, but they may be fed in limited amounts sliced and mixed with dry feed. The bitter-tasting water in which potatoes are cooked should be thrown away, especially if the tubers are not sound. According to Pott,[11] potatoes may furnish half the dry matter in the ration for fattening cattle and sheep, and one-fourth for horses. (**511**) Milch cows should not be fed more than 30 to 35 lbs., as larger amounts injure the quality of the butter. (**641**) Unripe potatoes and especially the sprouts of stored potatoes contain considerable *solanin,* a poisonous compound; hence in feeding potatoes any sprouts should be removed.

In Germany where machinery for drying potatoes has been perfected, the dried product is quite extensively fed to live stock. To produce 1 ton of the dried *potato flakes* from 3.5 to 4.0 tons of raw potatoes are required.

375. Jerusalem artichoke, *Helianthus tuberosus.*—The tubers of this hardy perennial, which resemble the potato in composition, are sometimes used for human food and for feeding stock. The tubers live over winter in the ground and enough are usually left to make the next crop. Due to this the plant may sometimes become a weed. Goessmann of the Massachusetts Station[12] reports artichokes yielding at the rate of 8.2 tons per acre. They may be harvested in the same manner as potatoes, or hogs may be turned in the field to root out the tubers. At the Oregon Station[13] 6 pigs confined to one-eighth of an acre of artichokes gained 244 lbs., consuming 756 lbs. of ground wheat and oats in addition to the tubers. Allowing 500 lbs. of grain for 100 lbs. of gain, we find that an acre of artichokes was worth 3,700 lbs. of mixed wheat and oats. The pigs made but little gain on artichokes alone.

Pott[14] reports that the leaves and stems may be cut when half the leaves are still green, without reducing the yield of tubers. This forage may be fed to sheep, goats, or dairy cows with good results. Despite the many enthusiastic endorsements of artichokes no community in this country seems to grow them continuously—a significant fact. (**511, 1002**)

376. Sweet potato, *Ipomaea batatas.*—The sweet potato, a southern crop grown as far north as New Jersey and Illinois, serves not only for human food, but also for feeding stock, especially swine, which do their own harvesting. Tho the average yield is less than 90 bushels per acre, some farmers raise fully 200 bushels.[15] The sweet potato is at its best on sandy

[11] Handb. Ernähr. u. Futter., II, 1907, pp. 363, 366-7.
[12] Mass. Rpt. 10. [13] Ore. Bul. 54.
[14] Handb. Ernähr. u. Futter., II, 1907, p. 196.
[15] Duggar, Southern Field Crops, p. 449.

soil. Keitt of the South Carolina Station[16] states that land which under ordinary cropping yields but 20 bushels of corn will produce 200 bushels of sweet potatoes per acre. Dodson of the Louisiana Station[17] considers sweet potatoes the best root crop for hogs for fall and early winter grazing. (**1004**) Conner of the Florida Station[18] found that sweet potatoes may be successfully substituted for half the corn in the ration of work horses, 3 lbs. of sweet potatoes replacing 1 lb. of corn. Scott of the same station[19] found that 100 lbs. of sweet potatoes was as useful as 150 lbs. of corn silage for dairy cows. While more valuable, sweet potatoes were also far more expensive to produce than the corn silage.

The vines, tho difficult to gather because they trail and take root at short intervals, are often utilized for feed, usually in the green state.

377. Chufa, *Cyperus esculentus.*—The chufa sedge, frequently a weed in damp fields on southern farms, produces numerous small, chaffy, edible tubers. These are relished by pigs, which are usually turned in to harvest the crop. As chufas are low in digestible crude protein, protein-rich feeds should be added to balance the ration. They grow best on light, sandy soils, yielding from 100 to 150 bushels of 44 lbs. each per acre. Like artichokes, the tubers remain in the ground uninjured thru the winter. Good crops of chufas have produced 307 to 592 lbs. of pork per acre, after making allowance for the other feed consumed by the pigs. (**1006**)

378. Cassava, *Manihot utilissima.*—Cassava, a bushy plant 4 to 10 feet in height with fleshy roots like those of the sweet potato, grows in Florida and along the Gulf coast. In the tropics varieties having bitter roots containing prussic acid are grown. These must be dried or heated before feeding. The sorts grown in the United States have sweet roots containing but a trace of prussic acid. From 5 to 6 tons of roots, carrying from 25 to 30 per ct. of starch, are produced per acre. They are used for the manufacture of starch and for cattle and swine feeding. At Muscogee, Alabama,[20] 200 steers and 100 hogs were fattened by using 1600 lbs. of cassava roots daily in place of grain.

Dodson[21] reports that in Louisiana a larger tonnage can be obtained from sweet potatoes than from cassava, and at about one-third the cost. This crop has never been important in the United States and its culture has declined greatly in the last 20 years. The cassava waste of starch factories should be dried for feeding. (**785**)

II. Miscellaneous Succulent Feeds

379. Cabbage, *Brassica oleracea.*—On rich ground cabbage gives as good returns of palatable forage as do root crops, but as more labor is required in its cultivation, it is but little grown for stock feeding. Cabbage is highly prized by shepherds when preparing stock for exhibition,

[16] S. C. Rpt. 1909, p. 32.
[17] La. Bul. 124.
[18] Fla. Bul. 72.
[19] Fla. Bul. 99.
[20] U. S. Dept. Agr., Farmers' Bul. 167.
[21] La. Bul. 124.

and is also used for feeding milch cows, Gill of England[22] considering it superior to rutabagas. Like other plants of the mustard family it should be fed after milking to avoid tainting the milk. When cabbage is raised for market, the small heads and the leaves may be fed to stock.

380. Kohlrabi, *Brassica caulorapa.*—This member of the mustard family, which is valued for its thickened, turnip-like stem, can be grown wherever rutabagas thrive, tho the yield is usually lower. According to the New York (Cornell) Station[23] kohlrabi is a good substitute for rutabagas in the Middle West where these roots have a tendency to run to neck and form little root. Kohlrabi stands well out of the ground and thus can be readily pastured by sheep, which also relish the leaves. This crop has not been known to taint the milk when fed to cows.

381. Rape, *Brassica napus.*—Largely thru the instrumentality of our experiment stations, rape is now extensively grown by stockmen thruout the United States. This member of the turnip family stores its nutriment in the numerous leaves and stems, the parts eaten by stock. The Dwarf Essex variety should be sown, birdseed rape being worthless. While rape can be used for soiling, it is best to let stock harvest the crop. Unless grown in rows, cattle will tramp down considerable of the forage while grazing. Rape is too watery for silage. The seed, which is inexpensive, may be sown in succession from early spring until August in the North and even later in the South, either broadcast, in drills and cultivated, or finally with corn just previous to the last cultivation.

From 6 to 12 weeks after seeding the crop is large enough for use. Zavitz of the Ontario College[24] reports a yield of 27 tons of rape forage per acre from 2 lbs. of seed sown in drills 27 inches apart, the crop having been cultivated every 10 days. In plot tests covering 15 years he secured an average yield of 19.2 tons per acre.[25] Rape endures quite severe frosts, therefore furnishing late autumn feed. It should never be eaten so closely that only the bare stalks remain, for the yield of new leaves will then be reduced. Animals on rape consume large amounts of salt, which should be freely supplied, as it tends to check any undue laxative effect of the forage. Sometimes stock must be taught to eat rape, but they later become fond of it.

Cattle which during the fall months have the run of a rape field, together with pasture, will go into winter quarters in high condition. To avoid tainting the milk of dairy cows, rape should be fed or grazed only directly after milking. Rape has its largest use for sheep and hogs, and since the animals gather the crop, the cost is low compared with the returns. Cabbage, rape, turnips, etc., like all cruciferous plants, have an unusually high content of sulfur, which may explain in part their value for sheep. (**875-6**) Access to clover or bluegrass pasture when on rape is highly advantageous to all stock, besides reducing the danger from bloat or hoven. Rape furnishes one of the best forages for hogs, and as

[22] Jour. Brit. Dairy Assoc., 1898.
[23] N. Y. (Cornell) Bul. 244.
[24] Ont. Agr. College, Rpt. 19.
[25] Ont. Dept. Agr., Bul. 228.

it somewhat more than maintains them, all the grain which is fed goes to make gain. (**982**, **992**) Pigs, especially the white breeds, running in rape when the leaves are wet, may suffer from a skin affection.

382. Kale, *Brassica oleracea,* var. *acephala.*—Coarse growing varieties of kale, a cabbage-like plant that does not form heads, are used extensively for soilage and pasturage in England and France. In this country kale is grown extensively only in the northern Pacific coast district, where "thousand-headed" kale, the common variety, is considered the best of soiling crops for dairy cows. On rich soil and with ample moisture yields of 35 to 45 tons and even more are secured.[26] In the mild climate of that section the crop is fed chiefly from October to April, as it endures considerable frost. Frozen kale should be thawed out before being fed. Like other members of the mustard family, it should be fed after milking to avoid tainting the milk. Kale is an excellent feed for sheep and swine.

A hybrid kale with thick, fleshy stems, called *marrow cabbage,* has excelled common kale in trials at the Western Washington Station.[27] The large leaves are harvested as they mature, and later the entire plant is cut and fed.

383. Pumpkins, squashes, and melons.—The pumpkin, *Cucurbito pepo,* is often planted in corn fields and the fruits used as a relish for horses, cattle, or pigs. The field pumpkin resembles the mangel in composition while the smaller garden pumpkin contains somewhat more dry matter. Hills of the Vermont Station[28] found 2.5 tons of pumpkins, including seeds, equal to 1 ton of corn silage for dairy cows. Tho often cooked for swine, trials show equally satisfactory results with the raw pumpkins. (**1003**) The tradition among farmers that pumpkin seeds increase the kidney excretions, tend to dry up cows, and hence should be removed before feeding, has no good foundation. The seeds contain much nutriment and should not be wasted. Pigs relish them, and they act as a vermifuge, freeing the animals of worms and putting the digestive organs in good condition. As the seeds are rich in protein and oil, eating an excess may cause digestive disturbance. Squashes and melons, especially pie melons, or citrons (also called cow melons), are sometimes fed to stock.

384. Apples and other fruits.—Windfall apples, pears, peaches, plums, oranges, figs, etc., may often be fed advantageously to stock and sound fruit may be thus used when prices are too low to warrant marketing the crop, for all farm animals relish these fruits. (**511**) Fruits contain somewhat more dry matter than roots, the chief nutrients being the sugars. Since they are low in protein, they should be used with protein-rich feeds. For dairy cows apples have about 40 per ct. of the value of corn silage, and apple pomace is practically equal to the same weight of corn silage. (**635**) In trials at the Utah Station[29] when fed with shorts

[26] Wash. Bul. 2, Special Series; Ore. Cir. 5.
[27] Wash. Bul. 2, Special Series.
[28] Vt. Rpt. 1908.
[29] Utah Bul. 101.

and skim milk to pigs 100 lbs. of apples equaled 9 to 15 lbs. of concentrates. Wilson of the Arizona Station[30] reports satisfactory gains with lambs fed ripe waste olives and alfalfa hay.

385. Spurrey, *Spergula sativa.*—On sandy land in northern Europe spurrey, which requires a cool, moist, growing season, is used as a catch crop for soilage and for green manure. The plant has proved of little value in this country, not being adapted to our hot summers.

386. Prickly comfrey, *Symphytum asperrimum.*—This plant, occasionally exploited by advertisers, has little merit in comparison with the standard forage plants. When carefully cultivated it gives quite large returns of forage which at first is not relished by cattle. Woll of the Wisconsin Station[31] found that red clover returned 23 per ct. more dry matter and 25 per ct. more crude protein than the same area of carefully cultivated prickly comfrey.

387. Mexican clover, *Richardsonia scabra.*—This annual, which is not a legume, is abundant in sandy land in sections of Florida and along the Gulf Coast, where it springs up spontaneously each summer after the manner of crab grass. It furnishes pasturage and, tho rather succulent, may be cured into hay.

388. Purslane, *Portulaca oleracea.*—The succulent weed of the garden, purslane, can often be used to advantage with swine. Plumb of the Indiana Station[32] fed brood sows 9 lbs. of purslane each daily, along with wheat shorts and hominy meal, and secured fair daily gains.

389. Tree leaves and twigs.—The small branches and leaves of trees are regularly fed to farm animals in the mountain regions of Europe where herbage is scarce, and in case of the failure of pastures or the hay crop they have been extensively used elsewhere. Tree leaves are more digestible than twigs, and the better kinds compare favorably with ordinary hay in feeding value. Leaves of the ash, birch, linden, and elder are valued in the order given. They are eaten with relish, especially by goats and sheep. These statements apply only to leaves gathered at the right stage and cured substantially as is hay from the grasses. Leaves which turn brown and drop from the trees in autumn are worthless for feeding farm animals. *Brush feed,* consisting of ground and crushed twigs, stems, and leaves, is used in certain mixed feeds as an absorbent for molasses. (**285**)

III. Plants of the Desert

Sagebrush, saltbush, and greasewood flourish on the plains of western America where alkali and common salt shut out many or even all of the ordinary forage plants.

390. Sagebrush.—Writing of the Red Desert of Wyoming, Nelson[33] says: "The amount of sagebrush, *Artemisia,* spp., consumed in the desert is simply amazing. . . . Whole bands (of sheep) will leave all

[30] Ariz. Rpt. 19.
[31] Wis. Rpt. 1889.
[32] Ind. Bul. 82.
[33] U. S. Dept. Agr., Div. Agros., Bul. 13.

other forage and feed on sagebrush for a day or two at a time. After that they will not touch it for some days, or even weeks.''

391. Saltbush, *Atriplex,* spp.—Many species of the saltbush, both annual and perennial, furnish forage to range animals on the western plains. The Australian saltbush, introduced into California and Arizona, will under favorable conditions produce 15 to 20 tons of green forage per acre, or 3 to 5 tons of dry, coarse hay which has about the same digestibility as oat hay. Peacock of New South Wales[34] reports that sheep fed saltbush in pens lost 3 lbs. in weight per head, but remained healthy during a period of a year. Others getting grass, hay, and saltbush made substantial gains. Saltbush mutton was dry and tough, but had a good flavor.

392. The greasewoods, *Sarcobatus,* spp.—The shrubby greasewoods likewise flourish on the plains and are browsed by range animals. Forbes and Skinner of the Arizona Station[35] report an analysis of greasewood which compared favorably with alfalfa in the amount of crude protein and other nutrients contained. Such forage is readily eaten.

393. Russian thistle, *Salsola kali,* var. *tragus.*—The introduced Russian thistle, now growing over great areas of the plains east of the Rockies, is used to some extent for pasture and hay. The mature plants are woody and loaded with alkali. It should be cut when in bloom and quickly stacked.

394. Cacti.—In western Texas, New Mexico, and Arizona, various cacti, principally prickly pear, *Opuntia,* spp., growing wild on the ranges, are used for feeding cattle, especially during periods of drought. The chollas and other types of cane cacti are also eaten by stock. Cacti grow but slowly unless the soil is good and there is reasonable rainfall during some part of the year. Because of its peculiar structure and habits this plant can survive protracted drought, tho it makes little or no growth at such times. Under favorable conditions the prickly pear may be harvested about once in 5 years. In Texas Mexican teamsters make free use of the pear for feeding their work oxen, and some rangemen have fed large quantities along with sorghum and cotton seed or cottonseed meal to their fattening cattle. Cacti may be fed where they grow by first singeing off the spines with a gasoline torch, after which the cattle eat them with apparent satisfaction. Under favorable conditions a man can singe the spines from 6 to 12 tons of standing ''pears'' per day. In some cases the pears are gathered in wagons and put thru machines which chop them in such manner that the spines are rendered more or less harmless.

Prickly pears are less watery than roots, containing on the average 16.5 per ct. dry matter, of which 3.4 per ct. is ash, and are lower in protein but somewhat higher in nitrogen-free extract. The young joints are more watery than those which are 2 years old or over, and cattle are said to prefer those which are more mature. Cane cacti contain a

[34] Agr. Gaz. N. S. Wales, 1906. [35] Ariz. Rpt. 1903.

higher percentage of dry matter than the prickly pears. Cacti alone do not provide a maintenance ration for stock. According to Vinson,[36] cattle in the deserts of Sonora, Mexico, subsist for 3 months of the year on little else than the fruits of cacti, but they become emaciated. When fed in large amounts with no dry feed cacti tend to produce scours. As cacti are all low in protein, this forage should be supplemented by protein-rich feeds, such as alfalfa hay or cottonseed meal. From trials at the Arizona Station[37] Vinson concludes that 6 lbs. or more of cholla fruit with 0.5 to 0.75 lb. of alfalfa hay will maintain a sheep in a lean but healthy condition.

In a trial by Griffiths[38] cows fed 3 lbs. cottonseed meal and 8 to 12 lbs. of rice bran per head daily ate about 150 lbs. of singed prickly pear, 6 lbs. of pear equaling 1 lb. of sorghum hay in feeding value. A lot of 27 steers fed a ration of 96 lbs. chopped prickly pear and 4.4 lbs. of cottonseed meal gained 1.75 lbs. per head daily, requiring 55 lbs. of pear and 2.5 lbs. of cottonseed meal per pound of gain.

Spineless cacti, which during recent years have been extensively advertised, have long been known in Mexico and the Mediterranean countries. The spineless varieties are not hardy where the temperature falls below 20° F. and are thus of limited value in the southwestern states. These cacti cannot survive on the open range because cattle will graze and destroy them, and moreover they must be enclosed by rabbit-proof fences, as these animals are fond of them. Griffiths[39] reports yearly yields of 20 to 25 tons of spineless cactus per acre without irrigation at Chico in the Sacramento Valley, California; this locality having an average rainfall of 23 inches. These yields were secured with expert cultivation and when a perfect stand was carefully maintained.

The chief importance of cacti will undoubtedly be to furnish emergency forage for stock in the semi-arid regions in case of drought, for these plants are able to utilize most efficiently small and irregular supplies of moisture. For this purpose plantations of the spiny cacti may be established on the open range, where they will be able to grow and hold their own until drawn upon in time of serious drought, for cattle will not graze them when other feed is reasonably abundant.

IV. Poisonous Plants

Only the briefest mention can be made of the leading plants poisonous to stock. One in trouble should send suspected specimens to the experiment station of his state or to the United States Department of Agriculture.

395. Plants carrying prussic acid.—Prussic acid, a most deadly poison, has been found in over 200 species of plants. It is present in the wild cherry, laurel, locust, vetch, Java bean, flax, etc. The leaves of the wild

[36] Ariz. Bul. 67.
[37] Ariz. Rpt. 21.
[38] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 91.
[39] U. S. Dept. Agr., Farmers' Bul. 483.

cherry, especially when wilted, are particularly fatal to cattle. Peters and Avery of the Nebraska Station[40] have shown that when the sorghums, both saccharine and non-saccharine, are stunted by drought, prussic acid may develop in such quantity as to bring death to cattle browsing upon them, the affected animals often dying soon after eating a few mouthfuls of the poisonous forage. While normal plants are entirely harmless, authorities advise caution in the use of the sorghums, kafirs, Johnson grass, etc., growing on rich soil, as well as in the use of second-growth and stunted plants. The poison is not found in wilted or cured sorghum or in sorghum silage, which are therefore always safe for feeding.

396. Ergot.—The seeds of rye and many grasses are sometimes attacked by a fungus which produces enlarged black, sooty masses, known as ergot. Occasionally hay or straw bearing the fungus severely injures cattle which are continuously fed thereon during winter. Ergot acts on the nervous system, depressing heart action and thereby restricting the blood circulation. In advanced cases the ears, tail, and lower parts of the limbs of affected animals lose warmth and sensibility, dry gangrene sets in, and the diseased parts finally slough away. Animals showing symptoms of this trouble should have their feed changed to remove the cause, and be warmly housed and liberally supplied with nourishing food.

397. Forage poisoning.—During recent years serious losses of horses and mules have occurred in various parts of the country, especially in the Central West, from forage poisoning, or blind staggers (cerebro-spinal-meningitis). This is caused by eating moldy feed, either corn grain, corn fodder, silage, or grass, or it may result from drinking water which has passed thru moldy vegetation. Cattle also may be killed by such poisoning but are less susceptible than horses or mules. Whenever poisoning is suspected the feed should be changed immediately, for the mortality is high in well-developed cases, the animal dying in some instances in 6 to 8 hours.[41] To prevent the disease care should be taken not to feed moldy, improperly cured, or otherwise damaged feed. Graham of the Kentucky Station[42] states that if moldy forage must be fed it should be given sparingly with other feed of good quality. When corn is at all moldy he recommends "floating" it. This consists of placing the grain in water, whereupon the damaged kernels will rise to the surface and may be skimmed off.

398. Cornstalk disease.—A mysterious ailment in the West at times attacks cattle turned into the stalk fields during fall and winter after the corn ears have been removed. All efforts to determine the cause have thus far proved futile. Alway and Peters of the Nebraska Station[43] investigated the losses from cornstalk disease in one county in Nebraska in which 404 farmers lost 1,531 head of cattle during a single fall. They state that no precaution and no feed or combination of feeds has so far

[40] Nebr. Bul. 77.

[41] Haslam, Kan. Bul. 173.

[42] Ky. Bul. 167.

[43] Nebr. Press Bul. 27.

been found to prevent or mitigate the losses from this disease. They further conclude that farmers in districts in which the disease is prevalent, unless they are to lose the valuable forage of their corn stalks, must choose between two alternatives: (1) Cutting the stalks when the corn ripens, shocking them in the field and feeding the fodder, thus avoiding all trouble. (2) Pasturing the standing stalks with the knowledge that they are liable to lose as many as one-twentieth of their cattle in an unfavorable season.

399. Corn smut.—At the Wisconsin Station[44] the senior author fed 2 milch cows on well-cleaned corn smut mixed with wheat bran, starting with a few ounces and increasing until 32 ounces of smut was supplied daily to each cow. At this point one refused her feed, but the allowance of the other was increased until 64 ounces, or 1 peck, was fed daily. This cow seemed to thrive on the smut and was growing fat, when she suddenly sickened and died. Smith of the Michigan Station[45] fed 4 cows on well-cleaned corn smut until each was eating from 1 to 10 lbs. daily. Only one cow showed any indisposition, and she recovered. In experiments by the Bureau of Animal Industry,[46] United States Department of Agriculture, corn smut was fed to heifers without harmful effect. It is reasonable to conclude that corn smut is generally harmless to cattle, tho animals becoming fond of it and eating inordinately may suffer harm.

400. Loco poisoning.—Great numbers of horses, cattle, and sheep have been lost on the great ranges of western America thru "loco" poisoning brought about by eating various plants, mostly legumes. The loss from this cause in Colorado alone has been estimated at a millon dollars annually.[47] "Locoed" animals have a rough coat and staggering gait, carry a lowered head, and show paralytic symptoms—in general, going "crazy." The studies of Marsh and Crawford[48] seem to show that the poisoning is due to the presence of barium salts in certain legume plants. Barium does not generally exist in the soil, so the dangerous plants are found only in certain districts. Loco poisoning is most prevalent in springtime when the ranges provide scant feed, and the emaciated animals are forced to subsist largely on plants which they would ordinarily reject. Well-nourished animals are rarely affected.

401. Castor bean.—The castor bean and the pomace remaining after the oil has been extracted contain a deadly poison. Castor beans or pomace accidentally getting into feeding stuffs sometimes cause mysterious deaths. Carnivan[49] reports that exposing castor oil cake to the air for 5 or 6 days or cooking the seeds or cake for 2 hours destroys the poison.

[44] Wis. Rpt. of Regents, 1881.
[45] Mich. Bul. 137.
[46] U. S. Dept. Agr., Bur. Anim., Indus. Bul. 10.
[47] U. S. Dept. Agr., Bur. Plant Indus., Bul. 121, Pt. III; Farmers' Bul. 380.
[48] Loc. cit. [49] Ann. Soc. Agr., Lyon, 1887.

402. Saltpeter.—Mayo of the Kansas Station[50] reports losses of cattle from eating corn forage carrying quantities of saltpeter in and on the stalks. The dangerous forage had been grown on land previously used as feed lots where the soil was excessively rich.

403. Miscellaneous poisonous plants.—The common horsetail, water hemlock, poison hemlock, death camas, several species of larkspur, cockle bur, woody aster, and many other plants are more or less poisonous to farm animals. As Marsh[51] points out, stock seldom eat poisonous plants by choice, but only when induced or compelled by the scarcity of other feed. When the grazing is short animals should therefore be kept away from spots definitely known to be infested with such plants. In moving herds or flocks on the range special precautions should be taken when it is necessary to pass over a trail that has been used by many others, for all good feed will have been consumed, and the stock will eat whatever is left.

[50] Kan. Bul. 49.

[51] U. S. Dept. Agr., Farmers' Bul. 536.

CHAPTER XVI

SILAGE—SOILAGE—THE PREPARATION OF FEED

I. Silage and the Silo

The preservation of beet leaves, beet waste, and other green forage by gathering into heaps or into earthen pits and covering with earth has long been practiced in Europe. In 1877 the French farmer, Goffart, published his "Manual of the Culture and Siloing of Maize and Other Green Crops," the first book of its kind, covering 25 years of practical experience. To Goffart belongs the credit of describing the first modern silo and of observing and recommending the peculiar merits and advantages of the maize (corn) plant for silage. In 1876 Francis Morris, Oakland Manor, Howard county, Maryland, made the first silage in America by putting whole corn forage into a pit dug in the ground and covering it with earth. The first silo in this country built partly above ground was constructed by Dr. J. M. Bailey of Boston, Massachusetts, in 1879. In the same year Mr. J. B. Brown of New York gave American readers a translation of Goffart's book, and in 1880 Dr. J. M. Bailey issued "The Book of Ensilage, the New Dispensation for Farmers." In 1881 Professor I. P. Roberts[1] at Cornell University, and the senior author[2] at the University of Wisconsin, built and filled the first silos used for experimental purposes in America. By these means silos and silage were brought prominently before the farmers of this country, and the interest which was awakened has steadily increased until the ensilage of fodders has become a factor of vast importance in American agriculture.

404. How ensiling preserves forage.—When green forage is packed firmly into an air-tight chamber, such as a silo, fermentations take place, caused both by the enzymes contained in the plant cells and by bacteria and yeasts carried into the silo on the forage. During these fermentations much of the sugar in the ensiled forage is broken down into organic acids, chiefly lactic acid (the acid in sour milk), with some acetic acid (the acid in vinegar), and traces of other acids. In these changes oxygen is taken up and carbon dioxid (carbonic acid gas) given off. At first the oxygen in the air which has been entrapped in the ensiled mass is used up, but if the mass has been well compacted, this is soon exhausted. The enzymes and bacteria then obtain the additional oxygen needed for these decompositions from the oxygen-containing compounds in the forage—chiefly the sugars. When the sugar in the forage has been changed into the acids the fermentation is checked, for the other

[1] Information to the authors.

[2] Wis. Rpt. on Amber Cane and the Ensilage of Fodders, 1881, pp. 60-69.

carbohydrates are attacked to only a small extent. It is due to this that well-matured corn or sorghum makes less acid silage than immature plants, which contain more sugar. Even tho an excess of sugar is present the fermentation comes to an end at length, for sufficient acid is finally produced to prevent both the further growth of the bacteria and yeasts and the action of the plant enzymes. During the fermentation processes the temperature rises somewhat, but if the mass has been well compacted, so that but little air is present, the temperature in the interior of the silo rarely reaches 100° F. The changes are therefore far less extensive than those which occur in the making of brown hay. (**334**)

Not only does the accumulation of acid automatically check the further action of the acid-forming enzymes and bacteria, but it also prevents the growth of undesirable putrefying bacteria, such as cause the decaying of meat. The poor-quality, foul-smelling silage which often results when such legumes as alfalfa, clover, or soybeans are ensiled alone is doubtless largely due to the fact that there is not enough sugar present in the plants to yield sufficient acid to check the growth of these putrefying bacteria. The high protein content of these plants also favors putrefaction.

After a few days the silage-making processes cease, and no appreciable changes will take place so long as the air is excluded. Instances are on record where silage made 12 to 14 years before has been found to be of excellent quality.

Tho the conversion of sugar into organic acids is the chief change which takes place in good silage other decompositions also occur to some extent. A considerable part of the protein is broken down by enzymes into amino acids (**11**), the silage sometimes containing 2 or 3 times as much of these cleavage products as the original fodder. However, as this splitting of the protein into simpler compounds is similar to the digestion which takes place in the digestive tract of the animal we need not suppose that the nutritive value is thereby necessarily impaired. (**49**)

405. Steaming silage.—It has sometimes been advocated that forage be steamed immediately after placing it in the silo, on the ground that the bacteria, yeasts, and enzymes are thereby destroyed, and the more or less perfectly sterilized mass thus preserved with little or no fermentation. However, Withycombe and Bradley found in digestion trials with cows at the Oregon Station[3] that steaming corn forage after ensiling reduced the digestibility of the dry matter 16 per ct., the crude protein 91 per ct., the ash 79 per ct., and the fiber, nitrogen-free extract, and fat to a slight extent. Hence, tho the steamed silage was admirably preserved and contained only half as much acid as ordinary silage, its feeding value was greatly reduced. (**83**)

406. Requisites of a good silo.—1. *Air-tight walls.* The silo walls must be air-tight, for if oxygen gains entrance the fermentations will continue and molds will grow, spoiling the silage. Such action takes place

[3] Ore. Bul. 102.

at the top of the silo where the mass is exposed to the air, but if the silage has been well packed and wet down, the impervious top layer of rotten material, which soon forms, prevents further entrance of the air. All doors must fit tightly, else the silage will spoil about the openings.

2. *Cylindrical shape.* In the early silos, which were rectangular structures, it was exceedingly difficult to pack the mass in the corners so that it would not spoil. With the devising of the cylindrical silo by King at the Wisconsin Station[4] this serious trouble was overcome, thereby greatly advancing the practice of ensiling forage plants. The cylindrical silo has now been commonly adopted, for besides the advantage of having no corners, it provides the largest cubic capacity for a given amount of building material, and the sides are strong and unyielding.

3. *Smooth, perpendicular, strong walls.* Unless the walls of the silo are smooth and perpendicular, cavities will form along the walls as the mass settles and the adjacent silage will spoil. The walls must be strong and rigid, for during the settling of the silage a great outward pressure is developed. This increases with the depth of the silo and, according to King,[5] reaches 330 lbs. per square foot of wall surface at a depth of 30 feet. After the silage has fully settled this lateral pressure ceases.

4. *Depth.* The early silos were shallow, and even tho the forage was well-tramped it was often necessary to weight the mass down to force out the air sufficiently. By making the silo deep the great pressure compacts all but the upper layers so that the losses thru fermentation are reduced to a minimum. The fact that the losses of nutrients are heaviest in the upper layers and surface of the silage is another reason for having the silo deep, because the loss per ton of total contents is thereby reduced. At the Wisconsin Station[6] King placed about 65 tons of green corn forage in an air-tight silo in 8 layers, and determined the loss in each layer, after standing from September to March. The dry matter lost in the respective layers was as follows: surface (eighth) layer, 32.5 per ct.; seventh layer, 23.4 per ct.; sixth layer, 10.3 per ct.; fifth layer, 2.1 per ct.; fourth layer, 7.0 per ct.; third layer, 2.8 per ct.; second layer, 3.5 per ct.; and bottom layer 9.5 per ct. While the surface layer lost over 32 per ct. of its original dry matter, the average loss in the first 5 layers from the bottom was less than 5 per ct., and the loss for the whole silo only 8.1 per ct.

407. Types of silos.—Silos may be constructed of wood, solid concrete, concrete blocks, brick, stone, glazed tile, or sheet steel. In the semi-arid regions pit silos, preferably with cement lining and curb, are extensively used, but these are impracticable in humid climates. In the southwestern states silos are sometimes built of adobe, reinforced with wire and plastered with cement. The choice between the various types of construction, all of which make good silos when well-built, will depend upon local conditions.

This work can present only the primary principles relating to silo

[4] Wis. Bul. 28., issued July, 1891. [5] Wis. Bul. 83. [6] Wis. Bul. 83.

construction, advising those interested to secure from the state experiment stations or the United States Department of Agriculture instructions concerning the form, materials, manner of construction, etc., as detailed in bulletins which are available for the asking.

408. Advantages of silage.—The widespread use of the silo for the preservation of forage is easily explained when we consider the advantages this system offers, the more important of which are:

1. At a low expense silage furnishes high-quality succulent feed for any desired season of the year. For winter feeding silage is far cheaper than roots and is as efficient a feed, except possibly in the case of animals being fitted for shows or milch cows on forced test. (**109, 365**) For summer feeding silage furnishes succulent feed with less bother and expense than do soiling crops. Dairy cows yield no greater product from soilage than from silage. (**420, 642**)

2. When crops are properly ensiled less of the nutrients are wasted thru the fermentations which take place than are lost when the forage is cured as hay or dry fodder. (**301, 330, 332**)

3. Silage, even from plants with coarse stalks, such as corn and the sorghums, is eaten practically without waste. On the other hand from 20 to 35 per ct. of dry corn fodder, even if of good quality, is usually wasted.[7] The use of silage thus permits the keeping of more stock on a given area of land, a factor of much importance on high-priced land.

4. Crops may be ensiled when the weather does not permit of curing them into dry fodder. In some sections of the South it is almost impossible to preserve the corn crop satisfactorily as grain and stover on account of the humidity, and also because rodents and weevils cause great loss in the stored grain.[8] Preservation as silage obviates both difficulties.

5. Weedy crops which would make poor hay may make silage of good quality, the ensiling process killing practically all the weed seeds present.[9]

6. The product from a given area can be stored in less space as silage than as dry forage. A cubic foot of hay in the mow, weighing about 5 lbs., contains approximately 4.3 lbs. of dry matter. An average cubic foot of corn silage from a 30-foot silo, weighing about 39.6 lbs., will contain 10.4 lbs. dry matter, or nearly 2.5 times as much. Dry corn fodder takes up even more space per pound of dry matter than hay. In climates where it is necessary to store fodder under cover this may be an added reason for the use of the silo.

409. Crops for the silo.—The suitability of the leading crops for silage has been discussed in detail in the foregoing chapters. Where it thrives Indian corn is the best silage plant. (**300**) The sorghums, including both the sorghos and the grain sorghums, are next in value and importance, as crops for silage. (**309**) In England meadow grasses have

[7] Skinner and Cochel, Ind. Bul. 129.
[8] Ferris, Miss. Bul. 158.
[9] Washburn, Vt. Bul. 170.

been converted into stack silage, in which case the decaying outside protects the interior of the mass—a practice which, however, is not gaining favor. Potts of Australia[10] reports that 3 tons of grass silage is estimated to be worth 1 ton of oat hay. A stack containing 200 tons of grass silage, opened after 10 years, furnished good feed. Georgeson of the Alaska Experiment Station[11] reports that fresh native grasses kept well when stored in a log silo made smooth inside, and that such silage satisfactorily maintained oxen during 3 winters. Green cereals are fairly satisfactory for silage, providing they are ensiled before the stems have become woody. (**318**) Since the hollow stems of these plants contain air, such forage must be closely compacted in the silo.

As a class the legumes have proved disappointing for silage when ensiled alone. (**342, 348**) Better results have been secured when such crops as alfalfa and clover are ensiled with plants which carry more sugar and less protein, such as green rye, wheat, corn, or sorghum. Except where weather conditions prevent curing these legumes into satisfactory hay, there is usually little need of ensiling them, for more reliable silage crops may usually be grown. When ensiled with corn or the sorghums, cowpeas and soybeans produce silage of high quality, rich in protein. (**357-8**) The refuse of pea canneries makes a silage much relished by farm animals. (**356**)

Such substances as beet pulp, beet tops, apple pomace, the waste from sweet corn canneries, and sorghum bagasse may be successfully ensiled in silos, or placed in heaps and covered with earth, or, if no better provision can be made, massed in large heaps without covering, in which case the outside portion on decaying forms a preserving crust. (**274, 356**) Cooke of the Vermont Station[12] found that ensiled apple pomace was preferred by cows to either hay or corn fodder, and concludes that it has a value equal to corn silage for cows. (**635**) Boyce of Australia[13] reports prickly pears making silage relished by cattle, the thorns softening and becoming harmless. Weeds and other waste vegetation may sometimes be advantageously ensiled. Featherstonhaugh of Australia[14] reports a case where 800 tons of ensiled thistles made satisfactory silage. Attempts to ensile cabbage, rape, and turnips have failed, the product being ill-smelling and watery.

410. Cost of silage.—The cost of silage per ton will vary widely depending on the price of labor, the yield of forage per acre, rent of land, etc. The following summary of recent data from 4 experiment stations gives the approximate ton and acre cost of growing a silage crop and placing it in the silo, including the rent of land, cost of fertilizers, man and horse labor, interest and depreciation on machinery and silo, and other charges, such as the cost of twine and fuel:

[10] N. S. Wales Gaz., Vol. 15, p. 82.
[11] Alaska Bul. 1.
[12] Vt. Rpt. 1903.
[13] N. S. Wales Gaz., Vol. 8, p. 505.
[14] N. S. Wales Gaz., Vol. 9, p. 71.

Cost per acre of corn silage

	Minnesota Station,[15] 201 acres Dollars	Illinois Station,[16] 147 acres Dollars	Ohio Station,[17] 115 acres Dollars	New Jersey Station,[18] 30 acres Dollars
Land rental	3.75	5.28	3.81	....
Manure or fertilizers	....	3.73	1.46 }	10.15
Seed	1.06	0.42	0.28 }	
Labor growing and cutting crop	5.19 }	12.26	14.63	8.27
Labor filling silo	4.12 }			
Twine	0.36	0.41	0.18 }	10.84
Coal	0.42	0.46	0.25 }	
Rental of power for cutter	1.39	1.21	1.36 }	
Interest and depreciation on farm machinery	1.56	1.76	1.34	....
Miscellaneous	1.13	0.58	0.42	....
Total cost per acre	18.98	26.11	23.73	29.26*
Cost per ton	....	3.30	....	3.65*

* Not including rent and interest and depreciation on farm machinery.
[15] Minn. Bul. 145. [17] Ohio Bul. 266.
[16] Unpublished data. [18] N. J. Rpt. 1913, pp. 414–415.

Carrier of the United States Department of Agriculture,[19] collecting data from 31 Wisconsin and Michigan farms, found the amount of corn forage placed in the silo daily varied from 3.3 to 7.4 tons for each man employed. Chase and Wood of the Nebraska Station,[20] gathering data for 341 acres of silage corn, found that the average cost per ton in filling silos was as follows: Cutting with binder, $.20; hauling, $.44; putting in silo, $.40; twine, $.03; and interest and depreciation on silo, $.32. Figuring corn at $.50 per bushel and stover at $.50 per acre the total average cost of the silage was $2.98 per ton.

411. Silage on the stock farm.—The use of silage has practically revolutionized the feeding of dairy cattle over a large part of the United States, and is fast assuming equal importance for the feeding of beef cattle and sheep. This succulent feed tends to keep the bowels normal, the body tissues sappy, the skin pliant, and the coat glossy, all of which mark the animals as in condition to make the most from their feed. (**109**) Furnishing at any time of the year a uniform supply of succulence nearly equal in palatability and nutritive effect to the pasturage of early summer, silage is eminently suited to the dairy cow. (**629-36**) As shown by the trials reviewed in later chapters, thru the wise use of silage for fattening cattle and sheep the cost of meat production may be materially lowered. (**774-83, 866-70**) Silage is especially valuable for breeding stock and young animals, which would otherwise often be wintered exclusively on dry forage. On too many farms stock cattle barely hold their own during winter. This means that for half of each year all the feed consumed goes for body maintenance, returning nothing to the owner, and serving only to carry the animals over winter and to pasture time, when they once more begin to gain in weight and thereby really increase in value. By the use of corn silage, combined with other

[19] U. S. Farmers' Bul. 292. [20] Nebr. Bul. 145.

cheap roughages, young cattle can be made to gain steadily all winter at small cost, so that with the coming of spring they will not only have increased in weight but are in condition to go on pasture and make the largest possible gains.

Silage is a valuable succulence for the breeding flock, but must be fed in moderation to ewes before lambing or weak, flabby lambs may result. (**884**) Good silage may also be used in a limited way with idle horses and those not hard worked in winter, especially brood mares and colts. (**510**) Spoiled, moldy silage should always be discarded, and special care must be taken to feed no such material to sheep or horses, which are much more easily affected thereby than are cattle. Silage which is unduly sour is apt to cause digestive disturbances with sheep. For all animals only as much silage should be supplied as will be cleaned up at each feeding. Care should be taken to remove any waste for this succulence spoils in a comparatively short time on exposure to the air. Frozen silage must be thawed before feeding. If then given before any decomposition takes place no harm will result from its use.[21]

On high-priced land and with high prices ruling for purchased concentrates and for labor the farmer will find the legumes and Indian corn or the sorghums his best crop allies. Heavily manured land will yield enormous crops of corn or sorghum forage carrying much grain, and this, utilized in part as dry forage, but mostly as silage, will materially extend the feeding powers of the farm in roughage rich in carbohydrates. Then let red clover, alfalfa, cowpeas, vetch, or other legumes be grown to furnish a protein-rich dry roughage. With an abundance of silage and legume hay the stockman need then supply only the minimum of rich concentrates which he must either grow or purchase. With this combination of feeds the number of animals the farm will carry is greatly increased, to the great advantage of both land and owner, and the cost of producing meat and milk is cut to the minimum.

412. Summer silage.—In many districts summer droughts frequently injure the pastures, making necessary the supplying of additional feed to maintain satisfactory production with dairy cows and other farm animals. Especially on high-priced land, where intensive agriculture must be followed, it is often desirable to keep more animals than can profitably be maintained entirely on pasture during the summer. Silage will admirably meet both these needs where enough animals are kept to feed off 2 inches or more of silage each day so that the surface will not decay. (**420**)

In trials covering 3 years at the Wisconsin Station[22] Woll, Humphrey, and Oosterhuis compared corn silage and soilage as summer supplements to pasture for dairy cows. In the production of milk and butter fat the silage ration was as efficient as that containing soilage, and also far

[21] U. S. Farmers' Bul. 556. [22] Wis. Bul. 235.

cheaper and more convenient. (642) To provide a succession of green feed for animals by means of soiling crops it is necessary to fit and plant comparatively small areas to different crops at different times. As the cut soilage will quickly heat in warm weather if placed in piles and will then be less palatable, a supply must be harvested each day or at least about every 2 days. Harvesting in small quantities and in all sorts of weather is inconvenient and expensive, and moreover the work must be done at the busiest season of the year. On the other hand, when corn or the sorghums are grown for silage the large fields are fitted, planted, cultivated, and harvested with labor saving machinery at a minimum expense, and feeding the silage takes but a few minutes daily.

Corn and sorghum return greater yields of nutrients than many of the crops it is necessary to include in a soiling system. Silage furnishes feed of uniformly high quality thruout the season, a goal which is difficult to attain by soiling, for one crop is often exhausted or too mature before the next is in prime condition for feeding. The years when drought is severe and pastures unusually short are the very times when soiling crops will be scant or may even fail. By means of the silo, the crop may be carried over from one year to the next, thus providing insurance against drought.

413. Filling the silo.—Provided the material is closely packed, it is not essential that green forage be cut into bits to preserve it in the silo. The legumes, such as alfalfa, clover, cowpea vines, etc., are often ensiled uncut, and some farmers ensile whole corn forage, tied in bundles. Especially with such coarse material as corn or sorghum, the forage packs much better when cut into short lengths by passing thru a silage cutter. For this reason and because of the greater ease in filling and especially in removing the silage, corn and sorghum are commonly cut before being ensiled, preferably into one-half to one inch lengths, for if cut longer than this stock may refuse the coarser portions.

When filling the silo the inpouring material should be thoroly mixed and evenly spread, so as to prevent uneven settling, as well as to make the mass uniform for feeding. As the friction of the walls retards the settling of the adjacent forage, material here should be kept slightly higher than in the center and should be especially well-tramped. The silage settles best when several days are occupied in filling the silo, for time is required for the forage to soften and settle and to expel the entangled air thru heat and the generation of carbon dioxid. After the mass has settled considerably, more forage may be placed in the silo, but any spoiled material should first be removed. If feeding is not to begin immediately, the surface should be wet down thoroly and tramped well several times the first week, when an impervious layer of rotten silage will form on top and only a few inches will be spoiled. To lessen the waste it is well to remove the ears from the last few loads of corn. A covering of a foot or so of cheap refuse, such as straw, weeds, or corn stalks, wet with water, will save the more valuable forage underneath. Oat or wheat grains scattered over the top of the ensiled mass soon germinate and form a mat which helps to keep out the air. The crust should not be disturbed until feeding commences, when all spoiled silage should be removed and discarded. When the forage becomes dry before being ensiled water should be added either to the mass in the silo or preferably to the cut forage as it passes thru the blower.

414. Danger from carbon dioxid.—In silo filling there is possible danger to those who go into the pit after an intermission, due to the generation of carbonic acid gas, which sometimes accumulates in sufficient quantity to prove fatal to life. The possibility of danger may be ascertained by lowering a lighted lantern or candle into the pit. If the light continues to burn at the bottom human beings can live in the same atmosphere, but if it goes out it means death to one entering the pit. The opening of a door low down in the silo will allow the poisonous gas to pour out, or pouring a lot of cut forage into the pit soon creates a circulation which removes the danger.

415. Weight of silage.—King[23] reports the weight of silage from well-matured corn 2 days after filling the silo to be as follows:

Weight of a cubic foot of corn silage at different depths

Depth	Weight at given depth Lbs.	Mean weight for whole depth Lbs.
1 foot	18.7	18.7
10 feet	33.1	26.1
20 feet	46.2	33.3
30 feet	56.4	39.6
36 feet	61.0	42.8

The second column shows that 10 ft. from the top corn silage weighs about 33 lbs. per cubic ft., while 36 ft. down it weighs 61 lbs., or nearly twice as much. The last column shows that the whole mass down to 10 ft. has a mean weight of about 26 lbs., while the whole mass in a silo filled to a depth of 36 ft. has an average weight of 42.8 lbs. per cubic foot.

416. Capacity of the silo.—The following table, chiefly from data obtained by King,[24] shows the approximate capacity of cylindrical silos for well-matured corn silage 2 days after filling. The depth indicated is the actual depth of the silage, not the height of the silo wall. It is therefore necessary to have the silo about 5 feet higher than the depth given to allow for settling.

The table shows, for example, that a silo 20 ft. deep and 15 ft. in diameter will hold about 59 tons of cut corn silage, one 32 ft. deep and 26 ft. in diameter about 346 tons, and one 40 ft. deep and 22 ft. in diameter about 340 tons.

[23] Wis. Bul. 59.

[24] Wis. Bul. 59.

Approximate capacity of cylindrical silos in tons of corn silage

Depth of silage in feet	Inside diameter in feet									
	10	12	14	15	16	18	20	22	24	26
20	26	38	51	59	67	85	105	127	151	177
21	28	40	55	63	72	91	112	135	161	189
22	30	43	59	67	77	97	120	145	172	202
23	32	46	62	72	82	103	128	154	184	216
24	34	49	67	76	86	110	135	164	195	229
25	36	52	71	81	91	116	143	173	206	242
26	38	55	75	85	97	123	152	184	219	257
27	40	58	79	90	102	130	160	194	231	271
28	42	61	83	95	109	137	169	205	243	285
29	44	64	87	100	114	144	178	216	256	300
30	47	67	91	105	119	151	187	226	269	315
31	49	70	96	110	125	158	196	237	282	330
32	51	74	100	115	131	166	205	248	295	346
34	56	80	109	126	143	181	224	271	...	...
36	61	87	118	136	155	196	243	293	...	...
40	70	101	138	160	180	228	282	340	...	...

417. Proper size of the silo.—The diameter of the silo should be gauged by the number and kind of animals to be fed from it, and its height by the length of the feeding period. The silo should be of such diameter that in the cooler part of the year at least 1.5 inches, and preferably 2 inches, of silage will be removed from the entire surface daily to keep the surface from spoiling. When silage is used for summer feeding somewhat more should be removed daily. The exact size of silo required may be computed from the length of the feeding period and the amount required daily for the different kinds of stock, as shown in the respective chapters of Part III. Knowing the number of animals of each kind to be fed, the entire amount of silage which will be consumed daily may be ascertained. The maximum diameter which the silo should have, may then be determined from the following: Two inches in depth of ordinary corn silage weighs about 3 lbs. per surface square foot near the top of the silo and 9 lbs. near the bottom, averaging about 6.6 lbs. in a silo filled to a depth of 30 feet. To use 2 inches from the surface each day the amounts indicated below should be fed daily from silos of various diameters.

Minimum amount of silage to be fed daily from silos of various diameters

Diameter of silo	Minimum amount of silage Lbs.	Diameter of silo	Minimum amount of silage Lbs.
10 feet	520	18 feet	1,680
11 feet	625	20 feet	2,075
12 feet	745	22 feet	2,510
14 feet	1,015	24 feet	2,985
16 feet	1,325	26 feet	3,505

In cold weather and when the silage is well packed, a somewhat smaller amount may be removed daily.

When the minimum diameter which the silo should have has thus been determined, the total amount of silage required for the desired feeding period may be computed and the dimensions for a silo of this capacity found by referring to the table in the preceding article. It should be borne in mind that silage in a relatively deep silo keeps better than in a shallow one, and that a deep silo is the most economical to construct. King[25] found that a silo 36 ft. in depth will store 5 times as much feed as one 12 ft. deep, due to the greater compactness of the stored mass. Many silos are now built 40 ft. or even more in depth. A silo 20 ft. in diameter will hold 4 times as much as one having half that diameter, while it costs but twice as much to build. Gurler[26] advises against silos over 25 ft. in diameter on account of the increased labor involved in removing the silage.

II. Soilage

Soilage means supplying forage fresh from the field to animals in confinement. It was first brought to public attention in this country by Josiah Quincy, whose admirable essays, printed in the *Massachusetts Agricultural Journal* in 1820, were later gathered into a booklet entitled "The Soiling of Cattle," long since out of print. Soilage, one of the most intensive forms of husbandry, is especially helpful where it is desired to concentrate labor and capital in maintaining farm animals on a relatively small area of land.

So far as known to the authors the word "soilage" was used for the first time in an editorial in the *New York Independent* of March 11, 1909 by E. P. Powell, the helpful, charming writer on rural topics. It is in a class with the words "leafage," "herbage," "forage," "pasturage," and "silage," and is here adopted as a valuable accession to our all too brief distinctively agricultural vocabulary.

418. Advantages and disadvantages of soilage.—Compared with allowing animals to gather their food by grazing, soiling has the following advantages: 1. With all crops, even grasses, which soon spring up again when grazed, a larger yield is secured by allowing the plants to nearly mature before harvesting than by pasturing them.[27] (**310**) 2. With a properly planned succession of soiling crops an abundance of palatable feed may usually be supplied thruout the season, so that the production of the animals will not decline if pastures become parched in midsummer. 3. None of the forage is wasted thru being tramped down by the animals or fouled with manure. 4. Less fencing is required. 5. In bad weather cattle will be more comfortable fed soiling crops in the stable than when grazing.

The greater expenditure for labor, seed, and fertilizer in producing the crops and for labor in cutting and carrying them to the animals are the chief disadvantages of soilage. In warm weather soilage will

[25] Physics of Agriculture.

[26] The Farm Dairy.

[27] Largely from Quincy, The Soiling of Cattle.

ferment and mold in a short time if left in piles. When but few animals are fed the green forage may be spread thinly on the barn floor, where it will keep, but soilage thus handled dries out and is less palatable. Where a considerable quantity is harvested at one time much labor may be saved by using the mower and horse rake. During wet spells the palatability of the soilage is reduced, and it is difficult to harvest and cart the food to the animals without injury to the land. On the other hand, pastures also suffer if grazed while wet.

419. Yield of pasturage and soilage.—Quincy reports that he maintained 20 cows in stalls, allowing exercise in an open yard, on the soilage from 17 acres of land where 50 acres had been required when the land was pastured.

The senior author[28] kept 3 cows for 122 days in summer on 3.7 acres of excellent bluegrass pasture at the Wisconsin Station and maintained 3 others in stable and yard for the same period by feeding soiling crops (green clover, fodder corn, and oats) from 1.5 acres. On this area a total of 44,835 lbs. of green forage was produced. The product from an acre under each system was as follows:

Yield of milk and butter from 1 acre of soiling crops and pasture

	Milk per acre Lbs.	Butter per acre Lbs.
From 1 acre of soiling crops..............	4,782	196
From 1 acre of pasture..................	1,780	82

This shows that in Wisconsin 1 acre of soilage crops equalled about 2.5 acres of good bluegrass pasture for feeding dairy cows.

Otis of the Kansas Station[29] found that it required 0.71 acre of soiling crops, half the area being alfalfa, to furnish a cow roughage for 144 days, while, when the cow was grazed, during the same period it required 3.6 acres of pasture composed of prairie and mixed grasses. After allowing for the grain consumed, soilage returned $18.08 and pasturage $4.23 per acre. Voorhees[30] found that to produce a ton of dry matter in soiling crops yielding from 3 to 4.5 tons of dry matter per acre annually, cost on an average $6.50, and that the total cost per ton of dry matter, including cutting and hauling to the barn, would be about $9.[31] The feeding value of this dry matter was nearly equal to that in purchased concentrates costing over $20 per ton.

420. The place of soilage on American farms.—It has been shown before (**412**), that silage is a more economical means of supplying succulent feed in summer than is soilage. On farms where too few animals are kept to prevent the molding of the surface of the silage as it is fed off or where a silo is not available, soilage should be provided to prevent the usual midsummer shrinkage in milk flow with cows, and in flesh with beef cattle or sheep. Under this system animals may be housed in darkened stables away from the flies during the heated portion of the day and fed liberally with fresh cut soilage, being turned to pasture at night for exercise and grazing. Young cattle will then continue

[28] Wis. Rpt. 1885. [29] Kan. Press Bul. 71. [30] Forage Crops. [31] N. J. Rpt. 1907.

growing, steers will increase in fatness, and cows yield a normal flow of milk during a period of the year when, because of heat, flies, and scant pastures, there is quite commonly no profit, and sometimes serious loss. It is also often advantageous to supply extra green forage during the fall months, even tho the pastures have then partly recovered their ability to supply nutriment.

Because of the high price of labor in this country it is not usually economical to maintain cattle in summer on soilage or silage with no pasturage in regions where good summer pastures may be provided. On high-priced land where it is desired to keep as many animals as possible on a given area such a system may be the most profitable. In Europe where labor is relatively cheap compared with land, a much wider use can economically be made of soilage.

421. Crops for soilage.—A long list of crops are well suited for soilage, including the various legumes, such as alfalfa, the clovers, field peas, cowpeas, and soybeans; the cereals, as rye, wheat, barley, and oats; the smaller grasses; and especially corn—sweet corn for early feeding and field corn later— and the sorghums. The adaptability of all these for soilage has been discussed in the preceding chapters.

Soiling crops should not be fed until reasonably mature. Green, immature plants are composed largely of water, and often cattle cannot consume enough of them to secure the required nourishment. (**23, 310**) For this reason, where quite green crops are fed, some dry forage should also be supplied.

422. A soiling chart.—Wherever soilage is practiced, a succession of crops must be carefully planned so that a continuous supply of green forage of the proper stage of maturity will be available over the period desired. This must be worked out by each farmer, bearing in mind the yields and seasons of maturity of the various crops which are suited to his soil and climatic conditions. In such planning it is helpful to prepare a soiling chart, similar to the following, worked out by Voorhees of the New Jersey Station,[32] which will show the area of each crop to be grown, the date of seeding, the period of feeding, and the estimated yield. Any attempt in this line will be more or less imperfect at first but may be modified from growing experience and close study to meet the local conditions.

This chart is an example of a practical system of soilage, since it records the actual attainment of one who most successfully specialized in this system for many years. The results here reported were obtained upon lands once regarded as of low agricultural value, brought to high productiveness by systematic soilage and fertilization. The table shows that 24 acres of land, producing 2 and sometimes 3 crops during the season, yielded 278.3 tons of green forage, supplying an average of 60.4 lbs. of green forage daily per head to an equivalent of 50 dairy cows from May 1 to November 1, a period of 6 months.

[32] Forage Crops, p. 35.

Soiling crops grown at the New Jersey Station for the support of a herd equal to 50 dairy cows for 6 months

Crops grown	Total seed used	Date of seeding	Period of cutting and feeding	Total yield
	Bushels			Tons
Rye, 2 acres	4.0	Sept. 27	May 1–7	9.4
Rye, 2 acres	4.0	Oct. 3	May 7–19	19.2
Alfalfa, 1 acre, 1st cutting	0.6	May 14	May 19–25	11.1
Wheat, 2 acres	4.0	Sept. 26	May 25–June 1	10.4
Crimson clover, 6 acres	1.2	July 16	June 1–21	42.8
Mixed grasses, 1 acre	....	....	June 21–26	8.3
Oats-and-peas, 2 acres	{ 4.0 3.0 }	April 2	June 26–July 4	12.4
Oats-and-peas, 2 acres	{ 4.0 3.0 }	April 11	July 4–9	8.2
Alfalfa, 2d cutting	....	....	July 9–11	2.1
Oats-and-peas, 5 acres	{ 10.0 7.5 }	April 19	July 11–22	16.4
Southern white corn, 2 acres	0.5	May 2	July 22–Aug. 3	17.7
Barnyard millet, 2 acres	1.4	June 19	Aug. 3–19	23.2
Soybeans, 1 acre	2.0	June 1	Aug. 19–25	8.8
Cowpeas, 1 acre	2.0	June 10	Aug. 25–Sept. 1	10.5
Cowpeas-and-kafir corn, 2 acres	{ 2.0 1.0 }	July 10	Sept. 1–16	24.4
Pearl millet, 2 acres	0.25	July 11	Sept. 16–Oct. 1	20.2
Cowpeas, 1 acre	1.5	July 24	Oct. 1–5	8.0
Mixed grasses, 5 acres (partly dried)	....	....	Oct. 5–27	20.0
Barley, 2 acres	3.5	Sept. 2	Oct. 27–Nov. 1	5.2
Total	....	....	....	278.3

III. The Preparation of Feeds

In the nomadic stage of husbandry the animals gathered their own food, the care of the owner ending when grazing, water, and protection from marauders were provided. With the change from primitive times the growing of plants and their conservation for animal use becomes an ever-increasing burden on the stockman. It is therefore a question of prime importance to determine to what extent such preparation of feeds as grinding or rolling grain, cutting or chaffing hay and coarse forage, and cooking various feeding stuffs is profitable.

The purpose of such artificial preparation of feed is to make it more digestible, to improve its palatability, or to permit the mixing of well-liked feeding stuffs with materials which would otherwise be refused. In studying any method of preparing feeds farmers must not only consider the beneficial effect, if any, on the animals, but must also determine whether such effect is marked enough to warrant the added expense incurred. The value of the different practices for each class of stock is discussed in detail in the respective chapters of Part III, but a summary of the conclusions there drawn will be helpful in showing the principles which should govern the feeder in deciding how far to employ such methods of preparation.

423. Grinding, crushing, or rolling grain.—As has been shown before (**83**), grinding, crushing, or rolling grain increases the digestibility only when animals fail to masticate the whole grain. In fact, grinding grain so finely that it is bolted with little chewing may sometimes decrease the digestibility because of imperfect mixture with the saliva. For all animals, such grains as bald barley or rice, which are unusually hard, or small seeds, such as millet, grain from the sorghums, or weed seeds, should ordinarily be ground. For animals with poor teeth or for young animals before their teeth are well developed, grinding grain in general is advisable. Ordinarily horses can grind their own oats and corn, and idle horses should always do so. For horses which are hard-worked and spend much of their time away from the stable the grain may well be ground and mixed with a small allowance of moistened chaffed hay. (**462**) A cow yielding a large flow of milk is a hard-worked animal, and her grain should usually be ground. (**668**) Where pigs follow fattening cattle to gather up any grain which escapes mastication and digestion there is no advantage in grinding corn or even shelling it, except perhaps toward the close of the feeding period when the cattle may be induced to eat more by grinding. Where no pigs run with cattle, it is usually economical to grind or crush the corn before feeding. (**735-6**) Except in the case of small or hard seeds, sheep with good teeth should grind their own grain. (**835**) While it pays to grind the small grains for pigs, there is no appreciable advantage in grinding corn for pigs weighing 150 lbs. or less. For older animals such preparation may sometimes be profitable. (**920-1**)

424. Cutting or chaffing forage.—Passing such coarse forages as corn or the sorghums thru a feed cutter or shredder is usually profitable, not because the portions consumed are digested more completely but because the animals waste less of the feed and the cut forage is more convenient to handle. This applies to soilage as well as to cured forage. (**297**) Where hay is palatable and consumed with little waste, it is ordinarily not economical to cut or chaff it for cattle or sheep, unless it is desired to mix the good-quality hay with other less palatable feed so that the whole will be consumed. Such preparation will often pay with roughage of poor quality as the animals will consume the cut forage with less waste. (**835**) The use of cut, or chaffed, hay and straw is common in establishments where large numbers of horses are kept. A little water lays the dust of chaffed hay, and the feeder can rapidly and accurately apportion the allowance for each animal. If meal is mingled with a limited portion of moistened chaffed hay, the mixture is in condition to be quickly masticated and swallowed so that it can remain longer in the stomach undergoing digestion—an item of importance with hard-worked horses which are in the stable only at night. (**459**)

Hay or straw should not be cut so fine that the animals will swallow it without chewing, or in the case of ruminants, that it will escape rumination. Kellner[33] recommends that straw be cut into pieces 1 to 1.4 inches

[33]Ernähr. landw. Nutztiere, 1907, p. 265.

long for cattle and 0.6 to 1 inch long for horses and sheep, green fodder and hay being cut somewhat longer.

425. Cooking feed.—In 1854 Professor Mapes voiced the popular opinion of those days when he wrote:[34] "Raw food is not in condition to be approximated to the tissues of animal life. The experiment often tried has proved that 18 or 19 lbs. of cooked corn are equal to 30 lbs. of raw corn for hog feed." Numerous scientific trials have since demonstrated, however, that in general cooking feed does not increase its digestibility, and in fact decreases the digestibility of the crude protein. (**83, 922**) This is shown by the trials of Ladd at the New York (Geneva) Station,[35] in which he determined artificially the digestibility of the crude protein in several common feeds, before and after cooking, with the results shown below:

Influence of cooking on digestibility of crude protein

	Per cent digested	
	Uncooked	Cooked
	Per ct.	Per ct.
Fresh corn meal	68.6	60.5
Old corn meal	72.6	63.2
Clover hay	67.7	53.3
Cottonseed meal	87.7	73.8

In each case cooking lowered the digestibility of the crude protein.

426. Steaming roughage for cattle.—Fifty years ago and even later, there could be found in this country establishments more or less elaborate used for steaming or boiling straw, corn stalks, hay, etc., for cattle feeding; it is doubtful if there is to-day a single one for this purpose. Feeding steamed hay to oxen at Poppelsdorf, Germany,[36] showed that steaming rendered the components of hay, especially the crude protein, less digestible. When dry hay was fed, 46 per ct. of the crude protein was digested, while in steamed hay only 30 per ct. was digested. The advice given years ago by the editor of an agricultural journal is as sound today as when given:[37] "The advantages are very slight and not worth the trouble of either building the fire, cutting the wood, or erecting the apparatus, to say nothing of all these combined, with danger and insurance added."

427. Cooking feed for swine.—While cooking feed for cattle was abandoned years ago, it is still practiced to some extent for swine. Fortunately the matter has been carefully studied by several experiment stations and definite conclusions reached. The most extended trial was one running 9 years at the Maine Agricultural College,[38] in which cooked and uncooked corn meal were fed. In each case there was a loss by cooking. It is not going too far to say that the investigators of this

[34] Trans. Am. Inst., 1854, p. 373.

[35] N. Y. (Geneva) Rpt. 1885.

[36] Hornberger, Landw. Jahrb., 8, p. 933; Armsby, Manual of Cattle Feeding, p. 266.

[37] Country Gentleman, 1861, p. 112.

[38] Ann. Rpt. of Trustees of the Maine State Col. of Agr., 1878.

subject usually began their studies in the full belief that the common feeding stuffs would be improved by cooking. The following are fair samples of the comments which commonly accompanied the reports of feeding trials with cooked and uncooked feed for swine.

Shelton[39] closes an account of his own findings with these words: "The figures given above need but little comment. They show as conclusively as figures can show anything, that the cooked corn was less useful than the raw grain. . . . Such entire unanimity of results can only be explained on the theory that the cooking was an injurious process so far as its use for food for fattening animals is concerned."

Brown of the Ontario Agricultural College,[40] reviewing several trials with cooked and uncooked peas and corn, wrote: "I am not at present prepared to say definitely what other kinds of food may do, raw or cooked, with pigs or other domestic animals, or how the other animals will thrive with peas or corn, raw or boiled, but I now assert on the strongest possible grounds . . . that for fast and cheap production of pork, raw peas are 50 per ct. better than cooked peas or Indian corn in any shape."

At the Wisconsin Station[41] the senior author, starting with the belief that cooking must increase the value of the common feeds for swine, after some 15 trials with cooked and uncooked whole corn, corn meal, ground barley, and wheat middlings, was forced to the conclusion that the Maine findings were correct. (**922**)

428. Stock bread.—In some sections of Europe bread is made from ground cereals, leguminous seeds, potatoes, cut straw, chaff, etc., principally for horses, tho sometimes for calves and cattle. The bread may be more appetizing than the original materials, but the chemical changes which take place as a whole do not increase its nutritive value. Such preparation can be generally recommended only where unpalatable feed may thereby be consumed with less waste. Unless baked into hard biscuits such bread will keep only a comparatively short time.

429. When cooking feed is advisable.—No one can review the large accumulation of data from the experiment stations without being convinced that generally it does not pay to cook feed for farm stock when such feed will be satisfactorily consumed without cooking. However, a few feeds, such as the potato and the field bean of the North, can be successfully fed to swine only after being cooked. Hard grains and seeds which can not be ground should be cooked or soaked. Musty hay and corn fodder are rendered more palatable and safe by steaming.

An occasional allowance of steamed or cooked barley or bran is especially helpful to horses because of its favorable action on the bowels, and this is doubtless true in lesser degree with fattening cattle. In winter, breeding swine and stock hogs are benefited by a daily feed of steamed roots, tubers, clover or alfalfa chaff, etc. with meal added. It is often advantageous to administer warm feed in winter, especially to swine, but warming should not be confused with cooking feed.

[39] Rpt. Prof. Agr., Kan. Agr. Col., 1885. [40] Ont. Rpt. 1876. [41] Wis. Rpt. 1893.

430. Soaking feed.—Corn becomes hard and flinty a few months after husking, and sometimes causes sore mouths, so little being then eaten that gains may cease or the animals lose in weight. Grain which is difficult of mastication should be either ground or softened by soaking, so that the animals may at all times consume full rations. Studying the results of 12 feeding trials with pigs at 8 stations, Rommel[42] finds a difference of slightly over 2 per ct. in favor of soaked over dry feed for fattening pigs. Grisdale of the Ottawa Experimental Farms[43] found a loss from soaking ground grain, while whole grain returned better gains when soaked. (**735, 923**)

431. General conclusions.—It has generally been assumed that by cutting, grinding, and cooking feed much labor is saved the animal, to the advantage of the feeder. This idea is based on the general theory that the less work the animal does in mastication and digestion the larger the net production of work, flesh, or milk. On the contrary, we know that the muscles of the body do not grow strong thru idleness, and that work and activity are conducive to bodily health, growth, and strength. We must therefore conclude that the organs of mastication and digestion should be kept working at their normal capacity. When cutting, grinding, cooking, or pulping brings more satisfaction to fattening animals soon to be slaughtered, and causes them to consume heavier rations, such preparation may pay, as it may also with exceptionally hard-worked animals that have but limited time for taking their rations. Feeding liberally and in an orderly manner, with ample variety in wise combination, is more important and helpful than making feeds fine and soft so that they can be quickly swallowed with little chewing.

[42] U. S. Dept. Agr., Bur. Anim., Indus., Bul. 47.
[43] Ottawa Bul. 33.

CHAPTER XVII

MANURIAL VALUE OF FEEDING STUFFS

Unless the plant food removed from the soil in crops is returned in some form, after a period of years reduced yields will tell the story of soil depletion. Already over great areas of our country the soil has been so "mined" of its original fertility that only by the liberal application of commercial fertilizers are remunerative crops now possible. This is shown by the fact that during 1913 there were sold in the United States over 6,800,000 tons of commercial fertilizers, worth about $150,000,000. In the South Atlantic states alone over 3,750,000 tons were used, including hundreds of thousands of tons of cottonseed meal. Southern planters feed great quantities of cottonseed meal to their crops —a rational agriculture would combine mixed cropping and stock growing with cotton raising. The meal from the cotton seed would be fed to farm animals and the resulting manure, still rich in fertility, would pass back to the fields, thereby giving a double return.

A judicious use of commercial fertilizers is highly commendable, but their place in general agriculture is to supplement deficiencies only after all the fertility in feeding stuffs that have been fed to live stock has been wisely and fully conserved.

432. Farm manure as a fertilizer.—Just as with commercial fertilizers, the value of farm manure is computed on its content of nitrogen, phosphoric acid, and potash, for of the constituents which plants remove from the soil only these need ordinarily be replaced. Phosphoric acid and potash, when naturally lacking in the soil, or when they have been carried off in crops or animals sold, must be replaced by means of commercial fertilizers or the manure of farm animals. The nitrogen needed may be indirectly obtained from the air by raising legumes, but in practice much is purchased along with phosphoric acid and potash.

Not only do farm manures supply plant food but the vegetable, or organic, matter they contain is important in increasing the productivity of the soil. As this vegetable matter gradually breaks down in the soil, the acid products formed help dissolve and make available to plants some of the otherwise insoluble plant food in the soil. Furthermore, the humus formed from the organic matter of manure helps retain moisture, improves the soil texture, renders it more resistant to wind action, etc. The value of organic matter to the soil is shown by the fact that on fields lacking in humus such crops as rye are often grown and turned under as green manure for the sole purpose of increasing the humus content.

Farm manures teem with bacteria of various kinds which cause chemical changes not only in the manure but also in the soil itself, converting insoluble plant food into forms available for crop growth.

After much practical work at the Ohio Station, Thorne[1] concludes that the fertilizing constituents of farm manures have as high a value per pound as those in such high-grade fertilizers as tankage, bone meal, and muriate of potash. In view of the highly beneficial effects which farm manure has in addition to supplying nitrogen, phosphoric acid, and potash, this is a conservative estimate. Because of the enormous use of commercial fertilizers thruout the civilized world, the nitrogen, phosphoric acid, and potash they carry have a recognized market price per pound, which fluctuates no more than that of other standard articles of world-wide commerce. In this country the average price of these ingredients to those who buy in large quantities is about as follows: Nitrogen 18, phosphoric acid 4.5, and potash 5 cents per pound. These values are used in this volume in computing the fertilizing value of feeding stuffs and the manures resulting from feeding them to farm animals.

433. Fertilizing constituents recovered in manure.—The proportion which is recovered in the manure of the total nitrogen, phosphoric acid, and potash supplied in the feed depends on the age and kind of animal, as shown in the following table from Warington:[2]

Proportion of nitrogen and ash of food which is voided by animal

	Nitrogen Per ct.	Ash Per ct.
Horse at work	100.0	100.0
Fattening ox	96.1	97.7
Fattening sheep	95.7	96.2
Fattening pig	85.3	96.0
Milch cow	75.5	89.7
Calf, fed milk	30.7	45.7

The mature horse at work is merely repairing his body tissues as they are broken down. (**140**) Therefore no nitrogen or ash (containing the phosphoric acid and potash) is stored in his body, but all the nitrogen and practically all of the ash is voided in the manure. (A negligible amount of ash is excreted in the perspiration.) With fattening animals whose bodies are nearly or quite mature, but little of the fertilizing constituents supplied in the food are retained in the body, over 95 per ct. of both nitrogen and ash being voided by the fattening ox and sheep. (**122**) With the pig fattened while not yet mature and storing nitrogen in his lean-meat tissues, about 85 per ct. of the nitrogen of the food is returned in the manure. As milk is rich in nitrogen and ash, the cow in milk voids only about 75 per ct. of the nitrogen and 89 per ct. of the ash contained in her food. (**150**) The young calf, growing rapidly in bone, muscle, and body organs, voids only 30.7 per ct. of the nitrogen and 45.7 per ct. of the ash in the food, storing the balance in

[1]Ohio Bul. 183. [2]Chemistry of the Farm, p. 214.

its body. (**113**) Considering the proportion of young animals and of those giving milk on the average farm, it has been estimated[3] that from the feed supplied farm stock about 80 per ct. of the nitrogen, phosphoric acid, and potash is ordinarily recovered in the feces and urine. The proportion of the organic matter of the food which is found in the feces will vary widely, depending on the proportion of difficultly digestible roughage in the ration. For well-fed ruminants and horses it ranges from about 20 to 35 per ct. As has been indicated before (**432**), the organic matter is a highly important factor in the beneficial action of the manure. No definite money value is, however, usually given to it in discussions of the fertilizing value of farm manures.

434. Influence of feed on the value of manure.—The animal creates nothing of fertilizing value, for it voids only that which it has eaten or drunk. Part of the fertilizing constituents is appropriated in the formation of flesh or milk, and the rest is voided in the excrements. The value of manure therefore depends primarily on the character of the food from which it originates. Foods rich in nitrogen, phosphoric acid, and potash yield rich manure; those low in these constituents make poor manure. In a trial reported by Warington,[4] cows fed 154 lbs. of mangels per head daily voided 88 lbs. of urine, containing but 0.12 per ct. nitrogen and 0.60 per ct. potash. Other cows fed 26 lbs. of alfalfa hay and given 66 lbs. of water daily voided only 14 lbs. of urine, which, however, carried 1.54 per ct. of nitrogen and 1.69 per ct. of potash, thus containing 13 times as much nitrogen and 3 times as much potash per pound as the urine from the cows eating mangels.

435. Fertility and manurial value of feeds.—Having shown that the value of manure depends primarily on the feeds eaten, we next consider the fertilizing constituents of typical feeding stuffs and animal products, shown in the following table, taken from the extensive data in Appendix Tables III and VI. For this table the fertility value of each feed per ton has been computed on the basis of what the total nitrogen, phosphoric acid and potash in that feed would cost if purchased in commercial fertilizers. The last column gives the manurial value[5] of each feed; i.e., the value of the manure which would result from feeding 1 ton of the feed to live stock. This has been computed on the assumption that, on the average, farm animals return in the manure about 80 per ct. of the total fertilizing value of the feed. (**433**) Obviously this value holds only when the manure is so cared for as to prevent the losses mentioned later. (**442-3**)

[3]Hart and Tottingham, Gen. Agr. Chem., 1913, p. 124; Van Slyke, Fertilizers and Crops, 1912, p. 300.

[4]Chemistry of the Farm, p. 218.

[5]Hart, Wis. Bul. 221.

Fertilizing constituents in feeding stuffs and animal products

	Fertilizing constituents in 1000 lbs.			Fertility value per ton	Manurial value per ton
	Nitrogen	Phosphoric acid	Potash		
	Lbs.	Lbs.	Lbs.	Dollars	Dollars
Concentrates					
Dent corn	16.2	6.9	4.0	6.85	5.48
Oats	19.8	8.1	5.6	8.42	6.74
Wheat	19.8	8.6	5.3	8.43	6.74
Wheat bran	25.6	29.5	16.2	13.49	10.79
Linseed meal, old process	54.2	17.0	12.7	22.31	17.85
Cottonseed meal, choice	70.6	26.7	18.1	29.63	23.70
Roughages					
Timothy hay	9.9	3.1	13.6	5.20	4.16
Red clover hay	20.5	3.9	16.3	9.36	7.49
Oat straw	5.8	2.1	15.0	3.78	3.02
Corn silage, recent analyses	3.4	1.6	4.4	1.81	1.45
Animals and animal products					
Fat ox	23.3	15.5	1.8	9.96	....
Fat pig	17.7	6.5	1.4	7.10	....
Milk	5.8	1.9	1.7	2.43	1.94
Butter	1.2	0.4	0.4	0.51	....

The fertility values given in the fourth column mean, for example, that the nitrogen, phosphoric acid, and potash removed from the soil in a ton of oat straw will cost not less than $3.78 if bought in the market in commercial fertilizers. A ton of corn (grain) removes $6.85 in fertility, and of wheat, $8.43. Because the legumes usually obtain much of their nitrogen from the air, only a part of the fertility in a ton of clover, worth $9.36, may have been taken from the soil. Clover hay is 80 per ct. richer than timothy hay and about 2.5 times as rich as oat straw in fertility. The fertility value of wheat bran is $13.49 per ton, while that of the wheat grain is only $8.43. This is because the starchy part of the grain, which forms most of the flour, holds but little fertility, while the outside portion, the bran, is high in nitrogen, phosphoric acid, and potash.

Of the feeds listed, cottonseed meal has the highest fertility value, $29.63 per ton; this explains why it has often been applied directly to the soil as a fertilizer. In 1913 the farmers of Connecticut[6] spread on their fields nearly 7,000 tons, or about 300 carloads, of this valuable feeding stuff, one of the richest and best for dairy cows and fattening cattle. Millions of dollars worth of cottonseed meal are annually applied by the planters of the South to the cotton fields to make another crop of cotton. Where the meal is first fed to live stock, the milk or flesh produced should easily pay its cost, and under good management also for a considerable share of the labor of feeding. With proper care and application, the manure resulting from each ton of meal fed would

[6]Conn. (New Haven) Rpt. 1913.

be worth $23.70, the manurial value, as surely as would the application to the same land of commercial fertilizers worth this amount.

436. Selling fertility.—The table in the preceding article further shows that those who sell such crops as hay, corn, and wheat part with far more fertility for a given sum of money than do those who sell animals or their products. The farmer who sells 1,000 lbs. of clover hay, worth $5 to $8, parts with about as much fertility as if he had sold 1,000 lbs. of fat ox or fat pig, worth $60 to $75, or more. Based on the selling price, milk carries considerable fertility from the farm, and butter practically none. Farm crops may be regarded as raw products, while farm animals, milk, wool, butter, etc., represent manufactured products. A large amount of raw material in the form of grass, hay, corn, etc., is put into animals, and the heavy waste or by-product resulting, in the form of manure, when carried back to the fields conserves most of the fertility. The farmer who feeds his crops to live stock is a manufacturer as well as a producer, with two possible profits instead of one, while his farm loses little of its fertility. The farmer who grows and sells grain, hay, and straw is selling a large amount of fertility, the need of which will surely be apparent as time goes on and his fields give smaller and smaller returns. Such a farmer is slowly but surely mining phosphorus and potash from his soil, which can be replaced only by some purchased material.

Virgin soils as a rule contain great quantities of available fertility, and the pioneer farmers in America, drawing upon Nature's store, have given little consideration to how their crops are fed and have not realized that they are steadily and often wastefully drawing on the store of fertility which represents their principal capital. The western farmer, when marketing corn or wheat, or the southern planter, when selling seed cotton, considers he is selling labor and rent of land. Rarely does he realize that he is also selling fertility, to replace which would cost a considerable part of all the crop brings. Rather than to reckon the value of his crop at the market price, he should recognize that its true value when sold from the farm is really the market price minus the value of the fertility which the crop removes from the soil.

437. Buying fertility.—Even in live-stock farming where little or no grain or roughage is sold and when proper care is taken of the manure, not all of the fertility removed in the crops is returned in the manure. The supply of nitrogen in the soil can usually be maintained by the growth of legumes, but sooner or later it is necessary to replace the small but steady loss of phosphoric acid and potash. Therefore in purchasing feeding stuffs, one should always consider not only the feeding value but also their worth as fertilizers. By purchasing those concentrates rich in phosphoric acid and potash, such as wheat bran and middlings, linseed meal, cottonseed meal, malt sprouts, etc., many live-stock farms are steadily being increased in fertility.

438. British practice.—In Great Britain, where many of the farmers are long-period tenants, the manurial value of feeding stuffs is recognized by law in a manner that tends greatly to the betterment and permanence of her agriculture. The Agricultural Holdings Act, which is the law governing the relations between landlord and tenant, directs that when a tenant is vacating his leasehold he shall be reasonably compensated for the improvements he has made. Among these, credit must be given for the fertilizing value of feeding stuffs which the tenant may have purchased and fed out, and also, under certain conditions, for the fertilizing value of grains produced on the farm and fed to stock. In order to furnish data to guide the valuers who serve in settlement between landlord and tenant, after full and extended study Lawes and Gilbert and later Voelcker and Hall of the Rothamsted Experiment Station drew up tables showing the compensation to be allowed for the fertilizing value of various feeds. The recommendations, as revised in 1913 and adopted by the Central Association of Agriculture and Tenant Right Valuers,[7] are that the tenant shall be credited as follows for all manure resulting from feeding purchased feeds to stock on the leasehold:

For all unused manure or that which has been recently applied to the land without a crop being grown thereafter, a credit of three-fourths of the total value of the phosphoric acid and potash in the feed is allowed. Because a greater loss of nitrogen commonly occurs in stored manure than in manure dropped in the fields by animals at pasture, a credit of 70 per ct. of the total value of the nitrogen is allowed when the stock have been fed at pasture, and of only 50 per ct. when they have been fed in barn or yard.

When one crop has been grown since the application of the manure, a part of the fertility thereby being used up, the credit allowed is only half that stated above. It is realized that the beneficial effects of farm manure persist much longer than 2 years, but owing to the difficulties of checking records for a longer period, the compensation is not extended over a greater time. The principles of the English law, as here set forth, should be drafted into every lease drawn between landlord and tenant in this country.

439. Composition and value of fresh manure.—Even tho the value of manure produced by animals of the same kind depends primarily on the nature of the feed supplied, it is important to note the approximate composition of manure from the different classes of farm animals. The following table, adapted from Van Slyke,[8] shows the percentage of water and the amount and value of the fertilizing constituents per ton in fresh manure, including both feces and urine, from the different farm animals.

[7] Jour. Roy. Agr. Soc., England, 74, 1913, pp. 104-119.

[8] Fertilizers and Crops, p. 291.

Composition of one ton of average manure from farm animals

	Water Per ct.	Nitrogen Lbs.	Phosphoric acid Lbs.	Potash Lbs.	Value Dols.
Horse manure..........	78	14	5	11	3.30
Cow manure...........	86	12	3	9	2.74
Sheep manure..........	68	19	7	20	4.74
Pig manure............	87	10	7	8	2.52

Horse and sheep manures contain less water than that of cows or pigs, and are known as "hot manures" because their low water content permits rapid fermentation when stored. On the other hand the voidings of the cow and pig form "cold manures," the high water content checking fermentation. Sheep manure has the highest value per ton, based on fertilizing constituents; pig manure the lowest. Mixed farm manures carry about 10 lbs. of nitrogen, 5 lbs. of phosphoric acid, and 10 lbs. of potash per ton.

440. Amount of manure voided.—Various methods have been suggested for computing the amount of fresh manure—feces and urine— produced by farm animals. Heiden[9] found that on the average 100 lbs. of dry matter fed to farm animals produced the amount of fresh manure shown in the first column of the following table. The second column gives the weight of manure plus bedding, computed from data compiled by Van Slyke.[10]

Manure from 100 lbs. dry matter fed to farm animals

	Manure Lbs.	Manure plus bedding Lbs.
Horse..............................	210	280
Cow...............................	384	427
Sheep..............................	183	285

Owing to the high water content of cow manure, a larger amount is produced from 100 lbs. of dry matter in the feed than in the case of the horse or sheep.

The amount of manure voided daily by farm animals varies widely, depending on the nature and amount of feed given and the age, activity, etc. of the animals. The following table, adapted from Van Slyke,[11] is a helpful approximation of the amount of manure voided daily by farm animals, per 1,000 lbs. live weight.

Daily production of manure by farm animals per 1,000 lbs. live weight

	Feces Lbs.	Urine Lbs.	Total manure Lbs.	Manure plus bedding Lbs.
Horse...............	39	10	49	65
Cow................	52	22	74	82
Sheep...............	23	11	34	53
Pig.................	50	33	83	99

[9] Storer, Agriculture, 1899, II, p. 289.

[10] Fertilizers and Crops, p. 303.

[11] Fertilizers and Crops, pp. 294, 303.

Based on live weight, the pig yields more manure than other farm animals, due to the heavy feed consumption per 1,000 lbs. live weight and the watery nature of the manure.

441. Fertilizing constituents produced yearly.—According to Van Slyke,[12] the approximate amount of nitrogen, phosphoric acid, and potash voided annually by farm animals per 1,000 lbs. live weight is as follows:

Annual yield of fertilizing constituents per 1,000 lbs. live weight

	Nitrogen Lbs.	Phosphoric acid Lbs.	Potash Lbs.	Value Dollars
Horse...........	128	43	103	30.12
Cow............	156	38	127	36.14
Sheep...........	119	44	126	29.70
Pig.............	150	104	128	38.08

The last column shows the total value of the fertilizing constituents, computed at the prices previously given. (432)

442. Losses in farm manures.*—From the foregoing it is evident that farm manure is one of the most valuable products of the farm. Yet many farmers who freely purchase commercial fertilizers allow much of the value of the manure produced by their live stock to be washed away in streams or otherwise dissipated. It is most important to realize that manure is a perishable product, and that unless proper care is taken over half its value may be lost. Plant food may be wasted thru: (1) Loss of urine, (2) loss by leaching, (3) loss of nitrogen by fermentation.

The importance of bedding to absorb the urine is shown in the following table from Van Slyke:[13]

Proportion of fertilizing constituents in urine and feces of farm animals

	Nitrogen in		Phosphoric acid in		Potash in	
	Urine Per ct.	Feces Per ct.	Urine Per ct.	Feces Per ct.	Urine Per ct.	Feces Per ct.
Horse.......	38	62	0	100	44	56
Cow........	51	49	0	100	85	15
Sheep.......	48	52	5	95	70	30
Pig.........	33	67	12	88	43	57
Average...	43	57	4	96	60	40

With the cow and sheep about half the nitrogen is voided in the urine; with the horse and pig somewhat less. Most of the phosphoric acid is excreted in the feces. The cow voids about 85 per ct. and the sheep 70 per ct. of the potash in the urine; the horse and pig over 40 per ct. For all farm animals, 43 per ct. of the nitrogen and 60 per ct. of the potash passes in the urine. Pound for pound the urine has a greater fertilizing value than the feces, except with the pig. The fertility in urine is also in solution and hence much more readily available to plants than that in the feces.

[12]Fertilizers and Crops, p. 295. [13]Fertilizers and Crops, p. 295.

*This discussion of the losses in manure and the care of this valuable farm product is necessarily very brief. For more complete information consult the standard works on Soils and Agricultural Chemistry.

A manure pile under the eaves, against the side of the barn, or manure lying for months in an open barn yard is a sight all too common on American farms. When manure is exposed to the leaching action of the rains, the losses are great, even amounting to half of the total value in periods of 2 to 5 months. Obviously, the loss falls on the constituents which are most soluble and therefore most quickly available to plants.

Thru fermentation a large share of the nitrogen in the manure may be dissipated into the air as ammonia or gaseous nitrogen. The strong smell which every farmer has noticed in close horse stables is due to the escaping ammonia produced by the breaking down of nitrogen compounds in the urine. In the hot fermentations which take place in dry, loosely packed manure, the temperature may rise high enough to cause "fire fanging," when as much as 80 per ct. of the nitrogen may be lost. Phosphoric acid and potash are not lost thru fermentation but heavy losses of these constituents may occur thru leaching.

443. Care of manure.—To prevent loss in manure, the urine should be saved by having tight gutters and using plenty of bedding. If possible, the manure should be drawn directly to the fields and spread each day. When this can not be done it should be stored, preferably under cover, in well-packed piles kept moist to prevent hot fermentation. If hogs or cattle have access to the shed, they aid in firming the pile. In Europe manure is often stored in pits or cisterns. When it is necessary to leave manure out of doors, the pile should be made high and compact so that rains will not soak thru and should be built with the sides perpendicular and the top sloping toward the center. It is impossible to prevent all waste in caring for manure, but under proper management not over 10 to 20 per ct. of the nitrogen and practically none of the phosphoric acid and potash will be lost.

Part III

FEEDING FARM ANIMALS

CHAPTER XVIII

FACTORS INFLUENCING THE WORK OF THE HORSE

The magnitude of the horse industry in the United States is apparent when we learn that there were in this country, according to the census of 1910, 23,015,902 horses valued at $2,505,792,588. These, with 4,480,140 mules and 122,200 asses and burros, make a grand total of 27,618,242 animals of the horse family, worth over $3,000,000,000. Despite the coming of the automobile and the auto-truck, for the decade ending 1910 the number of horses, mules, and asses in the country increased 11.6 per cent. The total value of these animals exceeds that of all the beef cattle, dairy cattle, sheep, goats, and swine combined.

To feed these work animals requires an annual expenditure of nearly $2,000,000,000. In spite of the enormous feed bill, less attention is given to the scientific and economical feeding of this class of live stock than to any other farm animals. Many a farmer, for instance, will carefully determine which of the feeds available for his dairy herd will furnish a well-balanced ration most cheaply. Yet he may forget that similar principles apply to the feeding of his work animals. An average of about 4 horses or mules are kept on each farm in the United States. When we learn in Chapter XIX how it is often possible thru the economical and proper selection of feeds and their rational administration to save 10 to 40 per ct. of the usual feed bill, with no injury, and in some cases even a benefit to the animals, it is evident that a careful consideration of the principles governing the feeding of horses will pay every owner in dollars and cents. Furthermore, it is just as essential to care for work animals so as to ensure their maximum efficiency as it is to lubricate carefully the vehicles and machinery they draw.

Before studying in detail the feeds for the horse and the methods of feeding and care, it is necessary to consider briefly the principles determining the value of the different classes of feeds for the production of work and the various factors which influence the amount of labor the animal can perform.

Most of the discussions which follow treat of the horse particularly, since over 83 per ct. of our work animals are horses, and nearly all of the scientific trials have been conducted with them. The same feeds may be used for mules, however, and the same principles of feeding and care apply to these animals. (Special hints on the feed and care of the mule are given in Art. **532**.)

I. The Relation of Feed to the Work of the Horse

The most complete investigations with the horse bearing on the relation of feed to work, are those of Wolff, Grandeau and LeClerc, and the more recent studies of Zuntz and his associates. Wolff's experiments were with a sweep-power constructed so that the amount of work performed could be measured. Zuntz, in conjunction with Lehmann and Hagemann, conducted hundreds of tests with horses working on a tread-power so built that the distance traveled and the work performed were accurately measured. The animals breathed thru a tube inserted in the windpipe, by which means the oxygen inhaled and the carbon dioxid exhaled were accurately determined. (**141**) To such gaseous intake and outgo was added that which passed thru the skin and vent, as determined by placing the animal in a Pettenkofer respiration apparatus. (**71**)

444. Work.—In discussing the production of work it is necessary to use the standard terms employed in its measurement, the foot-pound, the foot-ton, and the horse power. The *foot-pound* and *foot-ton* are terms which denote the work done in lifting a weight of 1 lb. or 1 ton, respectively, 1 ft. against the force of gravity. When the rate at which the work is done is taken into consideration the unit used is the *horse power,* which is the power required to lift a weight of 1 lb. at the rate of 33,000 feet per minute. If by means of rope and pulleys a horse raises a bucket of water weighing 100 lbs. from a well 330 ft. deep in 1 minute, it exerts a force equal to 1 H. P. The pull, or draft, exerted by the horse may be measured by a dynamometer, a crude form of which is a spring balance placed between the singletree or evener and the vehicle or object on which the pull is exerted. According to King,[1] the maximum pulling power of a horse when walking on a good road is about one-half its weight, but for steady and continuous work for 10 hours per day and at the rate of 2.5 miles per hour the pull should not be more than one-eighth or one-tenth the weight of the animal. The daily work performed by horses of different weights would accordingly be as follows:

Daily work performed by horses of different weights

	Horse-power produced	Foot-tons of work done
800-lb. horse	0.53—0.67	5,247— 6,633
1000-lb. horse	0.67—0.83	6,633— 8,217
1200-lb. horse	0.80—1.00	7,920— 9,900
1400-lb. horse	0.93—1.17	9,207—11,583
1600-lb. horse	1.06—1.33	10,494—13,167

The draft required to haul a 4-wheel wagon on various types of road is approximately as follows, according to King:[2]

[1] Physics of Agr., p. 490. [2] Physics of Agr., p. 436.

Draft required to haul a wagon on various types of road

Character of road	Lbs. draft per ton
Common earth	75 to 224
Gravel	75 to 140
Macadam	55 to 67
Wood block	28 to 44
Plank	25 to 44

This shows that it requires a draft, or pull, of 75 to 224 lbs., as measured on a spring balance placed between horse and load, to draw a load of a ton, including wagon, on a country earth road, while on a plank road the draft is but 25 to 44 lbs.

The ox draws a load equal to the horse, but ordinarily at only two-thirds the speed. A man's work is usually from one-sixth to one-tenth of a horse power, or about one-fifth that of an average horse. For a minute or two he can exert a full horse power or even more.

445. Digestion trials.—Since there have been relatively few digestion trials with the horse, we are usually obliged to use for this animal the coefficients of digestibility obtained with the ox or sheep. (**66**) While the horse digests the easily digestible feeds about as completely as do the ruminants, it falls below them in ability to digest the more difficultly digestible ones, as is shown in the following table from Wolff:[3]

Digestion coefficients of common feeds for the horse and sheep compared

	Dry matter	Crude protein	Carbohydrates		Fat
			Fiber	N-free extract	
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Corn					
Horse	89	77	70	94	61
Sheep	89	79	62	91	85
Oats					
Horse	67	79	20	74	70
Sheep	71	80	30	76	83
Alfalfa hay (excellent quality)					
Horse	58	73	40	70	14
Sheep	59	71	45	66	41
Clover hay					
Horse	51	56	37	64	29
Sheep	56	56	50	61	56
Meadow hay (good quality)					
Horse	51	62	42	57	20
Sheep	64	65	63	65	54
Wheat straw					
Horse	23	19	27	18	..
Sheep	48	..	59	37	44

It is shown that the horse digests corn, which is low in fiber, as well as does the sheep. On the other hand, it digests oats and meadow hay, which

[3]Land. Vers. Stat., 20, 1877; 21, 1878; Landw. Jahrb., 8, Sup. I, 1879; 10, 1881; 12, 1884.

contain considerable fiber, less completely. Of wheat straw the horse digests only 23 per ct., while the sheep digests 48 per ct. Both animals digest crude protein about equally well, but the digestive powers of the horse are markedly lower for fiber and fat. (**85**)

446. Influence of work on digestibility.—The effect of working a horse immediately after eating has been studied by Grandeau and LeClerc,[4] Tangl,[5] Colin,[6] Scheunert[7] and others. Their investigations show that moderate exercise, even immediately after the horse has eaten, tends to increase digestion in both the stomach and the small intestine, and also increases the rate of absorption of digested nutrients. Tho the rate of protein digestion is retarded for the first hour after eating, when the horse is exercised immediately after the meal, by the end of the second or third hour even more protein will have been digested than had the horse remained at rest. Contrary to some statements, exercise does not hasten the passage of food from the stomach into the small intestine, but apparently retards it. Severe labor may, however, depress digestion. Grandeau and LeClerc found that hard work at a trot lowered the digestibility of the protein 7 per ct. and of the fiber 13 per ct., compared with the amounts digested when the horse was allowed to rest after eating. The greater depression observed in the case of the crude fiber is doubtless due to the fact that this nutrient is digested mainly in the caecum and large intestine and is hurried thru these organs by the motion of the horse in action.

447. True value of feeds for work.—As previously shown (**78–80**), the true value of different feeds for work is not based merely on the amount of digestible nutrients they contain, for a varying percentage of the available energy in the digestible portion of the feed is used up in the work of mastication and digestion and thereby lost so far as useful mechanical work is concerned. By subtracting the energy thus used from the available energy which the digestible nutrients of any feed furnish, we will find the amount of net nutrients which may be used in the performance of such external work as propelling the body, carrying a burden, or pulling a load. We should remember, however, that the energy which is used up in mastication and digestion is all changed into heat, and so may aid in keeping the body warm.

Zuntz found[8] that the 1100-lb. horse, when drawing a load on a level road, will produce about 864.4 ft.-tons of work for each pound of net nutrients consumed in addition to the food required for maintenance. The following table shows the amount of work which various feeding stuffs will yield according to Zuntz, when fed to the horse which is already receiving enough food for maintenance at rest.

[4] Ann. Sci. Agron., 1884, Vol. II, p. 235.
[5] Pflüger's Arch. Physiol., 63, 1896, p. 545.
[6] Traite Physiol. Comp. Anim., 1886, p. 822.
[7] Pflüger's Arch. Physiol., 109, 1905, p. 145-198.
[8] Landw. Jahrb., 27, 1898, Sup. III, p. 431.

Possible work from 1 lb. of various feeds when fed to the horse

Feeding stuff	Dry matter	Crude fiber	Total digestible nutrients	Nutrients required for mastication and digestion	Net nutrients remaining	Possible work from 1 lb. of feed
	Per cent	Per cent	Lbs.	Lbs.	Lbs.	Ft.-tons
Corn	87	1.7	0.785	0.082	0.703	607.7
Horse bean	86	6.9	0.720	0.111	0.609	526.4
Peas	86	5.9	0.687	0.102	0.586	506.5
Linseed cake	88	9.4	0.690	0.125	0.565	488.4
Oats	87	10.3	0.615	0.124	0.491	424.4
Alfalfa hay	84	26.6	0.453	0.219	0.234	202.3
Potatoes	25	1.0	0.226	0.027	0.199	172.0
Meadow hay	85	26.0	0.391	0.209	0.182	157.3
Clover hay	84	30.2	0.407	0.239	0.168	145.2
Carrots	15	1.6	0.113	0.021	0.092	79.5
Wheat straw	86	42.0	0.181	0.297	—0.116	—100.3

The table shows that after supplying the horse with sufficient feed for maintenance, each additional pound of corn supplied, up to the capacity of the animal, will furnish energy sufficient to produce 607.7 ft.-tons of external work, or enough to raise a weight of one ton 607.7 ft. against the pull of gravity. Because of its high per cent of digestible nutrients and its low content of fiber, Indian corn is the most potential of all the given feeds for the production of work.

Feeds containing much fiber, such as hay and straw, furnish correspondingly less net food for the production of external work. The table shows that the work of masticating and digesting wheat straw requires more energy than the straw supplies. Hence the table shows a negative value of —100.3 ft.-tons for 1 lb. of wheat straw. As has been stated before (**80**), the energy used up in mastication and digestion all takes the form of heat. Therefore, unless the total work of digesting a ration containing straw produces more heat than is needed to warm the body, the straw will have a positive value for the production of the heat so required, and this value will depend upon the total amount of digestible nutrients it furnishes. On the other hand, if more energy is spent in masticating and digesting the ration than is needed to furnish heat to maintain the body temperature, then the energy of the straw will be wasted. This helps to explain why a larger amount of straw may be advantageously fed to idle horses than to those at work. As is shown later (**457**), even in the case of the horse at hard labor a certain volume or bulk is necessary in the ration. To furnish this necessary bulk a small amount of straw is sometimes used in place of other roughage, especially in Europe.

448. Maintenance requirement of the horse.—It is more difficult to determine the minimum amount of nutrients needed to maintain the weight of a horse than of the ox or sheep. This is due to the fact that any excess of nutrients supplied the idle horse above maintenance will not usually be wholly stored as flesh or fat, for confined horses, even those of quiet temperament, dissipate more or less energy thru restlessness and moving about, so that a ration which barely maintains them is really somewhat in excess of the theoretical requirement.

One method of determining the maintenance requirement is to feed a horse at rest a ration insufficient to maintain his weight, and then after a time gradually increase the supply of nutrients until the weight is barely maintained. Using this method Grandeau and LeClerc[9] were able to maintain the weight of each of 3 horses getting walking exercise for half an hour daily on a ration of 17.6 lbs. meadow hay, which supplied 6.1 lbs. of digestible nutrients, or 7 lbs. per 1000 lbs. live weight.

A more exact method is to give a horse gradually increasing amounts of a given feed, during successive periods, and determine in each period the maximum amount of work the animal can perform on the allowance and still maintain his weight. It is then possible to compute, by difference, the nutrients required for the performance of a given amount of work. By subtracting the nutrients expended in the work done during any period from the total nutrients supplied in that period, the actual maintenance requirement is found.

By the latter method Zuntz and his colleagues[10] found that to maintain the weight of the 1100-lb. horse and keep up the body temperature required 7.06 lbs. of digestible nutrients,[11] or 12.7 therms. It was found that the larger part of the nutrients, nearly 66 per ct., were required merely as fuel to maintain the temperature of the body. Indeed, it was necessary to supply only 2.43 lbs. of net nutrients (or 4.4 therms of net energy) to cover the amount used up in the internal work of the body and in repairing the body tissues.

This conclusion accords with the general experience, that idle horses can be maintained chiefly on such feeds as hay, corn stover, and straw, which furnish relatively little net energy but produce a large amount of heat in the body as the result of mastication and digestion. If the roughages are of sufficiently good quality the animals may be maintained on such feeds alone. As roughages are usually far cheaper sources of total available energy than the concentrates, maintaining idle horses on such feeds is obviously economical.

449. Protein required for maintenance.—In addition to supplying sufficient fuel to maintain the body temperature and enough net nutrients for the internal work of the body, as has been previously pointed out (94), the nutrients in the ration must include a certain amount of digestible protein to make good the small daily waste of nitrogenous tissues. In experiments by Grandeau and LeClerc,[12] 3 horses maintained their weight for 4 or 5 months on a ration of meadow hay furnishing an average of 0.54 lb. of digestible protein daily per 1000 lbs. live weight, the hay of course containing some amids beside the true pro-

[9] Warington, London Live Stock Jour., 1894, p. 9.

[10] Land. Jahrb., 27, 1898, Sup. III, pp. 422-426.

[11] Including fat x 2.4, the factor used by Zuntz as the relative fuel value for fat, compared with carbohydrates.

[12] Warington, London Live Stock Jour., 1894, p. 9.

tein. One of the horses gained 5 lbs. in 2 months on a daily allowance of only 0.45 lb. of digestible protein per 1000 lbs. live weight. In another case an allowance of 0.37 lb. of digestible protein daily per 1000 lbs. of live weight proved insufficient to maintain the nitrogen equilibrium. Evidently the minimum protein requirement for the horse ranges from 0.4 to 0.6 lb. per 1000 lbs. live weight, which is the same as that of the resting ox as determined by Armsby.

Most authorities maintain, and practical experience shows, that the health of animals is improved when they are fed more than the theoretical minimum of protein. In view of this, the Armsby standard recommends 1 lb. of digestible protein for the maintenance of the 1000-lb. horse at rest. (172)

450. Nutrients required for work.—We have considered the nutrients required to maintain the horse at rest and studied the value of typical feeding stuffs for producing external work. Let us next determine the amount of net nutrients which must be fed in addition to the maintenance requirement when the horse is to perform various kinds of work.

The work which the horse performs usually consists of a more or less complex combination of the following simple types:

(1) Locomotion, or merely traveling along a level course with no load.

(2) Raising the body, with or without a load, against the force of gravity in ascending a grade.

(3) Carrying a load.

(4) Draft, or hauling a load.

In the case of a horse drawing a load up a hill, we find all of these types combined. The horse is (1) advancing, and at the same time (2) raising his body. He is also (3) carrying the harness and (4) hauling the load. When he descends the hill he will even perform a fifth type of labor in bracing himself so as not to be forced down the hill too rapidly.

Zuntz[13] found that to perform these different types of work, the 1100-lb. horse carrying a 44-lb. harness required the net nutrients shown below, after he had already been supplied with enough feed for maintenance at rest:

Net nutrients required by horse for various kinds of work

	Net nutrients required Lbs.
Traveling without load, 1 mile on the level	
At a walking speed of 2.5 miles per hour	0.134
At a walking speed of 3.5 miles per hour	0.169
At a trotting speed of 6.6 to 7.6 miles per hour	0.254
Traveling 1 mile on the level when carrying a load of 220 lbs. at	
Walking speed of 3.4 miles per hour	0.210
Trotting speed of 6.9 miles per hour	0.323
Raising his body 100 feet	
In climbing incline of 10.7 per cent	0.060
Lowering body 100 ft. on a road with a 5 per cent dip, compared with traveling on the level, saves	0.025
Draft on level per 1000 ft.-tons, not including locomotion of body	1.157

[13] Landw. Jahrb., 27, Sup. III.

Could all the work done by a horse each day be accurately determined, it would be possible to resolve it into these different types, so that the nutrients required for its production might be calculated and a suitable ration computed. However, the table is of theoretical rather than practical interest, for the work of most horses varies greatly from day to day; moreover the usual work is complex and difficult to resolve into these simple types. Still, these figures are important in showing the influence of various factors on the energy expended by the horse in the work he performs.

451. Influence of speed.—It will be noted in the table that 26 per ct. more net nutrients are required when the horse walks a mile at a speed of 3.5 miles per hour than 2.5 miles. When his gait is hastened to a trot, nearly twice as much food is required per mile of travel as at the slower walk. Among the reasons why rapid labor generally consumes more power than slow motion, even when the distance traveled and the actual work done are the same, are the following: When a horse is walking at a rapid speed the work of the heart is greatly increased. In trotting or galloping the rise and fall of the body is much greater than in walking, and therefore a smaller part of the energy expended is available for onward movement. The temperature also rises, and much heat is lost by the evaporation of water thru the skin and lungs. The proportion of food producing heat is thus increased, while that appearing as work is diminished.

Fourier[14] found that the horse was at its best for drawing loads when moving at a rate of 2 to 2.5 miles per hour. When held down to a slower speed, and likewise as the rate of speed was increased beyond this figure, his efficiency decreased. At length, when a speed of 11.25 miles per hour was reached, less than one-tenth the maximum amount of work was accomplished. Grandeau[15] states that a horse walking 12.5 miles per day was kept in condition on a daily allowance of 19.4 lbs. of hay, while a ration of 24 lbs. was insufficient when the same distance was covered at a trot. A horse hauling a load 12.5 miles daily, the draft performed being equivalent to 1943 ft.-tons, was sufficiently nourished by a ration of 24.6 lbs. of hay, while one of 36.2 lbs.—all the horse would eat—was not enough to maintain its weight when the same amount of work was done at a trot.

Where it is necessary to develop maximum power continuously at considerable speed, the number of horses required for a specific work must always be greatly increased. Thus when horses were used on mail-coaches, even on the admirable highways of Great Britian, the proprietors maintained 1 horse per mile of route for each coach, each horse traveling only 8 miles and working an hour or less per day on the average, 4 horses drawing the loaded coach which weighed 2 tons. Draft horses moving 2.5 miles an hour are expected to do 7 times the work of coach horses moving 10 miles per hour.

[14] Thurston, The Animal as a Machine and a Prime Motor, p. 52.
[15] Warington, London Live Stock Jour., 1894, p. 49.

With running horses, the requirement of speed reduces the work performed (carrying the rider) to the smallest amount possible. Low writes:[16] "When it is considered that an ounce of additional loading to the same horse may make the difference of a yard or more in half a mile of running, it will be seen how greatly the weight borne may affect the issue in the case of horses of equal powers." (145)

452. Locomotion and carrying a load.—The preceding table shows what experience teaches—that the horse requires more nutrients to travel a mile when carrying a load than when merely moving his own body. We see that while only 0.169 lb. net nutrients are required in walking a mile at a speed of 3.5 miles per hour with no load, 0.210 lb. of nutrients, or over 24 per ct. more, are needed when a load of 220 lbs. is carried at about the same pace. When the same load was carried at a trot with a speed of 6.9 miles per hour the amount of nutrients required was increased by over 53 per ct.

Since in locomotion the body of the horse is alternately raised and lowered, it is difficult to measure the actual amount of mechanical work performed in order to compare it with the energy expended. Computations by Zuntz indicate that about 35 per ct. of the total energy expended by the horse moving on the level is actually transformed into the external work of advancing his body, the remainder of the energy producing no external work, but taking the form of heat.

453. Influence of grade.—The table further brings out the striking fact that for every 100 ft. the horse raises his body in ascending an incline of 10.7 per ct. (a rise of 10.7 ft. in 100 ft.), he requires 0.06 lb. of net nutrients in addition to the amount required on a level course. In other words, in raising his body 200 ft. in going up a grade he would use up almost as much feed as in traveling a mile horizontally. At the incline of 10.7 per ct. the horse was about as efficient in converting feed into muscular work as when traveling on a level course, about 34 per ct. of the total energy expended being transformed into the actual work of both propelling his body and raising it against the force of gravity. In climbing a hill the horse does much more work in traveling a mile than when going on a level course, for besides propelling his body, he must raise it against the force of gravity. Including both the work of ascent and the work of locomotion, Zuntz found that in ascending the grade of 10.7 per ct. at a speed of 3.1 miles per hour the horse expended more than 3 times as much energy as in walking the same distance on the level at but a slightly faster pace. In the latter case he was merely propelling his body and not raising it against the force of gravity. At the steeper grade of 18.1 ft. in 100, nearly 5 times as much energy was expended as when moving on a horizontal course.

In going down a gentle incline, owing to the pull of gravity, less energy was expended than in moving on a level road, resulting in a saving of nutrients, such saving being greatest when the down grade was about 5 ft.

[16] The Breeds of the Domestic Animals of the British Isles.

in 100. If the grade was steeper, the horse expended energy in bracing himself to check too rapid progress. When the downward grade reached 10 ft. in 100, as much energy was expended as when traveling on a level, and on a still steeper down grade the amount of energy expended was greater than that expended on the level.

The saving of feed by the proper use of wagon brakes in a hilly country is evident when we consider the energy the horse spends in descending a steep hill. Here he must not only brace himself to hold back his own body, but must also struggle to hold in check the heavy weight of the wagon.

454. Draft.—The preceding table (**450**) shows that after deducting the energy necessary for merely moving the body on a level course, 1.157 lbs. of net nutrients were required by the horse for each 1000 ft.-tons of draft on a level course. The horse is slightly less efficient as a machine in performing draft than in moving his body along a level course or in raising it against the force of gravity, for only 31 per ct. of the total energy expended was actually turned into draft. In drawing a load up a grade of only 8.5 ft. in 100, but 23 per ct. of the energy expended was actually turned into work. This was due to the fact that when performing draft up that grade more work was done per minute, and this led to an increase in the rapidity of breathing and the over-exertion of certain groups of muscles, with the result that more energy was wasted as heat and less was utilized in moving the load.

455. The nutritive ratio for work animals.—We have seen before that under normal conditions the non-nitrogenous nutrients—carbohydrates and fats—furnish the energy necessary for the production of muscular work, and that no more protein tissue is usually broken down during work than during rest. (**140**) Hence, as Kellner[17] points out, there is a great similarity between the nutrient requirements of mature working and mature fattening animals. After growth is completed and the protein tissues and organs of the body have reached full size, both working and fattening animals need only so much crude protein in their food in excess of maintenance requirements as is necessary to insure complete digestion of the ration. The remainder of the nutrient requirements, whether for producing fat with the ox or performing work with the horse, may be met thru a sufficient supply of carbohydrates and fat. (**143**)

Accordingly it is not necessary and is, furthermore, often not economical to furnish as much digestible protein in the ration as stated in the Wolff-Lehmann standard, which places the nutritive ratio at 1:7.0 in the case of light work, 1:6.2 for medium work, and 1:6.0 in heavy work.

Grandeau and Alekan[18] found that when horses working at a trot were fed rations of corn, sugar, and oat straw, furnishing but little crude protein and having extremely wide ratios, varying from 1:21 to 1:28, the ration still contained sufficient digestible crude protein to keep them in excellent condition. Kellner[19] found that horses were able to perform

[17] Ernähr. landw. Nutztiere, 1907, p. 443.
[18] Ann. Sci. Agron., 1901, II, p. 38.
[19] Landw. Jahrb., 9, p. 665.

hard labor without deterioration on a ration having a nutritive ratio of 1:9. Grandeau fed 3 horses during a whole year, sometimes on a ration of horse beans and straw having a nutritive ratio of 1:3, and again on one of Indian corn and straw having a ratio of 1:10. While on these rations the horses were either resting in the stall, exercising at a walk or trot, working on a sweep at a walk or trot, or finally working before the carriage. The effect of the rations was about the same in all cases, and any difference was in favor of the corn-and-straw ration having the wider ratio. These and other experiments, as well as practical experience, show that the nutritive ratio for work horses may vary widely without injury so long as the minimum requirement of crude protein is satisfied.

We should remember, however, that when more than 8 to 10 parts of digestible non-nitrogenous nutrients (carbohydrates + fat $\times$ 2.25) are supplied to one part of digestible protein, the digestibility of the ration is decreased. (**84**) Most authorities agree also that a supply of protein in excess of the actual minimum requirement has a beneficial stimulating influence on the animal. It would, therefore, not seem advisable to feed to horses a ration having a wider nutritive ratio than 1:8 to 1:10, except possibly under unusual conditions when protein-rich roughages or concentrates were not at hand, or were unusually high in price.

McCampbell[20] of the Kansas Station studied this question in his experiments at Fort Riley, the most extensive yet carried on with horses in the United States. From trials in which prairie hay and corn were fed with and without a nitrogenous supplement, he concludes that a ration having a wider nutritive ratio than 1:8 is inadvisable. It is not necessary to employ protein-rich concentrates to secure this nutritive ratio when legume hay forms the larger part of the roughage allowance.

456. Ration for the work horse.—We have seen how it is possible to analyze the work a horse does, and determine the amount of net nutrients he requires for each type. In practice, however, in only a few instances is it possible to determine the nutrients in this manner, because of the complex and varying nature of the work. We must, therefore, use some simpler method in computing a ration for the horse. As shown in the preceding article, the Wolff-Lehmann standard advises more protein than is necessary, and is hence often uneconomical. Kellner[21] has embodied the findings of Zuntz in his standards, shown in the following table, which states the amounts of digestible protein and net energy required by the horse at light, medium, and heavy work per 1000 lbs. live weight. Altho such a classification of work performed is somewhat vague, it is still helpful in practice. Murray[22] states that for the 1000-lb. horse, light work means the performance of from 250 to 500 ft.-tons of work per hour, ordinary work 500 to 750 ft.-tons, and heavy work 750 to 1000 ft.-tons. For the convenience of American readers, the requirements of net energy, as set forth by Kellner, have been converted into therms.

[20] Kan. Bul. 186.
[21] Ernähr. landw. Nutztiere, 1907, p. 453.
[22] Murray, Chem. of Cattle Feeding, 1914, p. 153.

Requirements of horses at light, medium, and heavy work

	Required per 1000 lbs. live weight Digestible protein Lbs.	Net energy Therms
Horse at light work	1.0	9.8
Horse at medium work	1.4	12.4
Horse at heavy work	2.0	16.0

It will be noted that the horse at heavy work is given twice as much protein as when at light work, while the net energy supply is increased by only about 63 per ct. This is due to the fact that the horse at severe labor is benefited by a fairly liberal supply of protein. The requirements of the work horse as determined by Zuntz and McCampbell have been stated by the authors in terms of dry matter, digestible crude protein, and total digestible nutrients, and are given in Appendix Table V.

457. Severe work.—The more severe the labor which the horse performs, the larger must be the supply of net nutrients. Since the ration must not have undue bulk, this necessitates a large proportion of concentrates, high in net energy content. On the other hand, the more severe the labor the smaller must be the allowance of roughage, for coarse feeds are of low value for producing work, and when given in undue amount hinder breathing, thru the distension of the digestive tract, thus placing an increased burden on the already hard-worked animal. However, some roughage must be supplied even during severe labor, for, as is shown elsewhere, horses fed no roughage but given an abundance of oats, which are rather high in fiber, soon show loss of appetite and impairment of the digestive functions. (107) It must be remembered that rich feed, carelessly administered, brings danger; hence especial care must be used in feeding the horse at severe work.

Wolff cites the intense work of the mail-coach horses on the route from Plieningen to Stuttgart, Germany. Two strongly built, spirited horses, in good flesh, drew a heavy mail coach, often carrying 8 passengers, up and down the mountain road 35 miles daily, trotting at the speed of 5.4 miles per hour. They were fed daily 22 to 24 lbs. of oats mixed with cut straw, and hay without limit, of which they ate very little—often none at all. Under these severe conditions these horses received sufficient fiber in the oats and cut straw, and hence instinctively refused hay.

Formerly the German army horse was fed only 11 lbs. of oats, 5.5 lbs. of hay, and some cut straw during the maneuvers, when often traveling over 40 miles a day, covering about equal distances at the walk, trot, and gallop. It is not surprising that on this ration, containing only about 8.8 lbs. of digestible nutrients, the horses, which performed about 11,900 ft.-tons of work daily, lost heavily in weight, and that many were unfitted for further military service.

458. Variations in body weight.—During exercise and work a loss in body weight occurs due to the heavier oxidation or burning of the nutritive fluids of the body and to the largely increased evaporation of water. Grandeau and LeClerc[23] found that 2 horses lost on the average 2.3 lbs.

[23] Ann. Sci. Agron., 1888, II, p. 276.

each when walked for 148 minutes without drawing a load, while on hauling a load at a trot for 79 minutes each lost 9.3 lbs. A horse performing a certain amount of work at a trot gave off 20.6 lbs. of water vapor, nearly twice as much as when doing the same amount of work at a walk, and over 3 times as much as when at rest. Such losses diminish the amount of energy available for the production of work.

Rueff[24] found, after making corrections for food and droppings, that farm horses at medium work lost 7.7 lbs. each during 11 hours. A horse carrying a 176-lb. load lost 11 lbs. in 25 minutes and regained only 1 lb. in 24 hours. A 14-yr.-old blind stallion ridden 90 minutes by a 166-lb. rider lost 33 lbs., regaining 22 lbs. the following day. Von Lutzow[25] found that 20 draft horses, weighing about 1750 lbs., each lost from 44 to 122 lbs. when put at hard work for 2 weeks. In a 3-day rest period only 3 horses regained their original weight.

Boussingault[26] found the maximum variation in the weight of 2 horses on the same keep and care during 15 days to be 25 and 28 lbs. respectively. A horse put on the scales at 4 o'clock after fasting weighed 1051 lbs. one morning, 1060 lbs. the next morning, and 1038 lbs. the third morning. This shows the necessity of carrying on feeding experiments for considerable periods and with several animals in order to escape, or rather lessen, the errors which are introduced into the calculations thru accidental variations in the weights of the animals studied.

II. Preparation of Feeding Stuffs for the Horse

459. Chaffed hay.—In large establishments chaffing or cutting the hay given to horses is usually advisable, because the cut roughage can then be accurately administered according to the needs of each animal, dust can be allayed, and the feeding operations more systemized and expedited. Horses that have been on the street all day and have worked to the limit may be given meal mixed with a small portion of the moistened chaffed hay, some of the nourishment thus being passed to the stomach more quickly than is possible when feeding long hay. On this point Lavalard,[27] summarizing extensive experience with omnibus and cab horses in Paris, writes: "For the past 4 or 5 years we have chopped coarse fodder, using a ration of equal parts of hay and straw, and have found this practice the most economical for several reasons: Straw may thus be made to form an integral part of the ration, and the proportion of hay and straw may be accurately regulated. Furthermore, horses waste much less of such fodder. . . . The feeding of chopped fodder has brought about a considerable saving and permitted greater uniformity than was previously the case in our experiments." On the other hand, having in mind farm horses, Lindsey of the Massachusetts Station[28] holds that there is no particular advantage in cutting hay. (424)

[24] Von Gohren, Naturgesetze d. Fütterung, p. 370.
[25] Deut. Landw. Presse., 36, 1909, p. 285.
[26] Ann. Sci. Agron., 1884, II, p. 330; Rural Economy, p. 397.
[27] Expt. Sta. Rec., 12, p. 12.
[28] Mass. Bul. 99.

460. Cooked feed.—The custom of cooking even a small portion of the feed given to horses has almost ceased. Johnstone,[29] who had the practice thoroly ingrained into his nature by early Scotch experience, out of his later observations writes: "Time was when I considered the feeding of sloppy stuff a necessity in properly wintering brood mares, but experience has shown me that dry food is best. Therefore I prefer uncooked food. . . Time was when I believed that for stallions during the season it was an excellent plan to give a mash of boiled barley every Wednesday and Saturday night. . . . The experiments have, however, shown that the addition of this material to a horse's grain ration makes no appreciable difference in the manner in which the grain is digested." (**425-9**)

461. Soaked grain.—Wolff[30] found that healthy horses with good teeth utilized beans and corn equally well, whether fed whole and dry or after having been soaked in water for 24 hours, care being taken in the latter case to guard against loss of nutrients. Ear corn that is so dry and flinty as to injure the horse's mouth should be soaked or ground. Whole wheat and barley should always be soaked if they cannot be ground, or, better, rolled. (**430**)

462. Ground grain.—Investigations have shown that when horses are fed whole oats mixed with cut straw or hay the percentage of kernels passing thru the alimentary tract unmasticated is much smaller than when the whole oats are fed alone. From his extensive studies with thousands of cab, omnibus, and army horses in France, to which cut straw or hay was usually fed, Lavalard[31] concludes that the advantages gained by grinding oats were not covered by the expense. In some of the experiments the horses showed better appetites for whole than for ground oats. Grisdale of the Ottawa Experimental Farms[32] likewise concludes that where oats are mixed with bran and cut hay there is no advantage in grinding if the horses have good teeth. Whether it will pay to grind oats when not fed with cut roughage will depend on how well the horse masticates the grain and on the expense of grinding. A profit from crushing oats is claimed by several large feed stables. As shown later (**475**), thruout the corn belt corn is usually fed on the cob or as shelled corn, tho some authorities recommend the use of corn-and-cob meal or coarsely ground corn meal. It is reasonable to hold that when horses are hard worked and have but little time in the stable, or when their teeth are poor, it is well to grind their grain. All small, hard grains, such as wheat, barley, rye, and kafir, should always be ground or, better, rolled.

III. Watering the Horse; Salt

463. Time for watering.—On theoretical grounds various authorities have advised watering the horse before giving him grain, to prevent possible flushing of the grain out of the stomach into the small intestine.

[29] The Horse, p. 77.
[30] Landw. Jahrb., 16, 1887, Sup. III, p. 21.
[31] Expt. Sta. Rec., 12, p. 12.
[32] Ottawa Expt. Farms Rpt., 1905.

Tangl[33] of Budapest, whose investigations concerning the time of watering horses are the most complete of any recorded, found that horses may be watered before, after, or during meals without interfering with the digestion or the absorption of the food they eat. All methods are equally good, tho circumstances may favor one over the other. A horse long deprived of water, or having undergone severe exertion, should be watered before getting his feed. An animal accustomed to a certain order of watering should not be changed to another order, for such change diminishes the appetite. Horses drink the greatest amount of water when it is given after they have been fed, and the least when it is supplied before they are fed. In some cases watering before feeding somewhat decreased the appetite. Tangl shows that the only important point in this whole matter, about which there has been so much discussion and dogmatic assertion, is to adopt a reasonable, convenient system of watering, and then rigidly adhere to it. It is dangerous to allow a horse to gorge himself with water when very warm, but a moderate drink taken slowly will refresh him without harm resulting.

464. Amount of water consumed.—The amount of water which horses will drink depends upon many factors, the most important of which are the individuality of the animals, the temperature of the air, the nature of their food, and the amount of work performed. Grandeau and LeClerc[34] found that 2 Paris cab horses when drawing a load at a walk consumed 16 per ct. more water than when walking but drawing no load. On trotting with no load the amount was increased 6 per ct., and on drawing a load at a trot 85 per ct. over that consumed when walking without a load.

Merrill of the Utah Station[35] found that horses fed timothy hay drank 79 lbs. of water each daily, while on alfalfa hay they drank 10 lbs. more. One of 2 horses getting alfalfa hay drank 21 lbs. of water more per day than the other. Morrow of the Oklahoma Station[36] reports that during hot weather in August a pair of farm mules drank 350 lbs. of water in 1 day—an extremely large amount. In making provisions for water, from 10 to 12 gallons, or 100 lbs., daily should be allowed for each horse. (**103**)

465. Salt.—The horse shows great fondness for salt, and for his well-being it should be regularly supplied. Horses at hard work require more than those laboring less severely. Roberts[37] states that 4 horses on dry feed ate 28 pounds of salt in 56 days, or 2 ounces per horse daily.

IV. Miscellaneous Factors Influencing Efficiency of Horses

466. Exercise.—The Arabs have a saying, "Rest and fat are the greatest enemies of the horse." The horse is par excellence the creature of motion, and in its feeding and management we should hold this point ever in view. The prudent horseman will bear in mind that correlative with

[33] Landw. Vers. Sta., 57, 1902, p. 329.
[34] Ann. Sci. Agron., 1888, 2, p. 276.
[35] Utah Bul. 77.
[36] Okla. Rpt. 1898.
[37] The Horse, 1905, p. 311.

liberal feeding there must be hearty exercise or severe labor, and that these conditions may be happily balanced. As soon as hard labor ceases, or constant and vigorous exercise is over, it will be found absolutely necessary to reduce the allowance of food if the proper balance is to be maintained. The idle horse should be limited to less than half the grain given while on regular duty, and in some instances it were better to give none, provided the roughage supplied be of good quality.

A colt fed heavily on suitable nutrients will grow rapidly and develop good bone and strong muscle, provided at all times there be a proper balance between exercise and feed. The highly fed colt should be out of doors from 8 to 10 hours a day, and should move several miles each day either in the field, on the track, or both. A mature horse should receive regular exercise, traveling not less than 5 to 6 miles daily, to maintain health.

467. The stable.—Proper ventilation of the stable is most important in maintaining the health of the stabled horse. Cool, well-ventilated quarters are far preferable to warm, close stables. Captain Hayes[38] states that in some large city stables of Russia the temperature is often kept 80° F. above that of the outside air in winter. Under these conditions trouble from influenza, inflammation of the eyes, and diseases of the respiratory organs are common. On the other hand, in the cavalry remount stables, roomy, clean, and well-ventilated, the horses keep in excellent health. He further states that previous to 1836, the mortality of horses in the French army was enormous, the annual loss varying from 180 to 197 per 1000 animals. Enlargement of the stables and better ventilation reduced this mortality to less than one-seventh the former figures. In all cases horses should be protected from drafts, and judgment must be used in blanketing them in extreme weather.

468. Blanketing and clipping.—Horses at work prove more efficient and last longer when reasonably protected against sudden changes in temperature and cold rains. It is important to blanket the horse in cold weather whenever his work ceases and he is forced to stand in the cold for even a short time. Stable blankets keep the coat in better condition, but when they are used it is especially necessary to protect the horse when standing idle out of doors.

The heavy coat which the horse grows for winter protection has certain disadvantages with the work animal under his artificial conditions. The horse with a long coat sweats unduly at work and his system is thereby enervated and relaxed, rendering him especially subject to colds. As it is difficult to completely dry such a horse after a day's work, it may often be advisable to clip him early enough in the fall to permit the growth of a lighter coat for protection before severe weather begins. However, he should not be fall clipped unless he is carefully protected from cold at all times when not working. Horses are often clipped in the spring after the shedding process has begun, but before the new coat has

[38] Stable Management and Exercise, 1900, p. 198.

started, thus, it is claimed, preventing as great a draft on the animal's system and certainly obviating the annoyance of the shedding coat, especially disagreeable in the case of gray horses.

469. Grooming.—As the horse at severe labor gives off several pounds of perspiration daily, when this evaporates considerable solid waste material is left on the animal's coat. Thoro and careful grooming is necessary to remove such body waste and keep the pores open and the skin healthy. Aside from the better appearance which results, proper grooming pays in the greater efficiency of the hard-worked animal. It is best to groom the work horse at night after a severe day's work, so that he may rest more comfortably. As idle horses running at pasture sweat little, consume green grass and other laxative foods, and have abundant opportunity to roll, grooming is unnecessary. While grooming should be thoro, a dull currycomb is preferable to a sharp one, and a brush should be used on the tender head and legs.

470. Care of teeth.—The teeth of the horse often wear irregularly, especially those of old horses, leaving sharp points and ragged edges that cause pain, prevent proper mastication of food, and in extreme cases actually cause starvation. Many horses that are poor in flesh and wear staring coats, despite a reasonable supply of food, owe their condition to poor teeth alone. The teeth should therefore be frequently examined and cared for, the irregularities being removed by a float or guarded rasp. The crowns, or caps, of the first, or milk teeth, are also apt to remain too long in the young horse's mouth, causing crooked permanent teeth; these crowns should be removed with forceps.

471. General hints.—To be most efficient in converting the energy of his feed into useful work, the horse must labor in a properly fitting harness. The collar needs special attention, for the capacity of many a horse is decreased because he wears an ill-fitting collar. It is vitally important that his feet be properly shod, so that the weight and wear are evenly distributed on the joints of the ankle. The other mechanical principles which determine the efficiency of work, such as the correct use of eveners, the proper adjustment of traces and of line of draft, the distribution of the load on the wagon, and the influence of size of wheel, width of tires, and character of road bed must all be given due consideration. In starting the day the horse should be gradually warmed to his work, so that his collar will be shaped to his shoulders, his muscles in proper trim, his bowels relieved, and breathing and heart action quickened before he is put to extreme exertion. It is likewise well to cool him off gradually at the end of a trip or of the day's work before returning to the stable. That he may rest in comfort, his stall should be well bedded.

No other farm animal is so strongly the creature of habit as is the horse, and in no way is he more so than in the matters relating to food and its administration. Sudden changes in quantity and variety should be avoided. A quick change from oats to corn may bring on colic, but changing from corn to oats is less dangerous. An abrupt change from old to new hay or oats, or from late to early cut hay, is hazardous. Wilted grass or new mown hay is more dangerous than fresh grass. Horses are especially susceptible to poisoning thru eating moldy grain or forage. (**397**) Any unusual feeding stuff, such as silage, roots, apples, etc., should be given in small quantities at first, and changes in kind and quantity of any food should be made gradually. It is best to mix and feed several kinds of concentrates together rather than feed them separately. As a rule some hay should be fed at the same time the concentrates are given, in order to distend the stomach and intestines properly. As is shown in the following chapter (**492**), more horses are injured by gorging on hay than by being given too little.

472. Supervision of feeding.—In stables where many horses are maintained, a group or row of animals should remain in the care of the same attendant, the whole establishment being under the watchful supervision of the superintendent. While we can estimate quite closely the amount of food to be given a hundred or a thousand horses, there should always be modifications and concessions to individual members of the establishment to be recognized and provided for by the guiding mind,—one horse should have a little more than the regulation allowance, and the next possibly a little less, the object being to keep each in the desired condition. Usually it is not well to leave the feeding of horses to their own driver, for he has likes and dislikes, and the favorites are quite certain to receive more than their proper allowance of grain, while the others suffer. A watchful superintendent must ever be on the alert to see that each animal secures the needed provender.

CHAPTER XIX

FEEDS FOR THE HORSE

I. Carbonaceous Concentrates

At any point of observation we usually find the common ration for the horse restricted to one or two kinds of grain and the same limited number of roughages. In the northern Mississippi Valley states the ration is quite generally confined to timothy hay and oats. In the South, Indian corn is the main concentrate, fed with dried corn leaves, legume hay, and other roughages. Where sugar cane is grown, blackstrap molasses is an important source of energy for work animals. On the Pacific coast crushed barley is the common grain, with hay from the cereals. Passing to other countries we find an interesting array of articles in the diet of the horse, tho usually no large number in any one locality. In Europe various oil cakes and beans often form part of the concentrate allowance. In some districts stock bread is commonly employed. Thruout Arabia, Persia, Egypt, and Algeria the only grain is barley, usually mixed with barley or wheat straw which has been thoroly broken by the native threshing machine. In northern India and Bombay, a sort of pea, called gram, is the usual food. Bamboo leaves are fed[1] as a complete substitute for ordinary grass and hay in the hill districts of eastern Burmah. In France, Spain, and Italy, besides the grasses, the leaves of limes and grape vines, the tops of acacia, and seeds of the carob-tree are all employed. "In some sterile countries," according to Loudon,[2] "horses are forced to subsist on dried fish, and even vegetable mould. In parts of India, salt, pepper, and other spices are made into balls, as big as billiard balls, with flour and butter, and thrust down the animal's throat."

With this brief survey of some of the foods employed in the nourishment of the horse, let us consider in detail the feeding stuffs of importance in the United States.

473. Oats.—No other grain is so keenly relished by horses of all classes and ages and so prized by horsemen as the oat, the standard of excellence with which other concentrates are compared. Oats are the safest of all feeds for the horse, in part because the adherent hull, tho of low nutritive value, gives such bulk that not enough of this grain can be eaten at one time to cause serious troubles from gorging, and so there is little danger from possible errors in measuring the grain allowance. (**223**) On account of the hulls there is, likewise, less tendency than with corn for this grain to pack in the horse's stomach where there is much less churning or mixing motion than with the ruminants. (**39**)

[1] Hayes, Stable Management and Exercise.

[2] Encyclopedia of Agr., 1886; Article, Feeding of Horses.

For mature horses with good teeth and ample time for masticating and digesting their food, it will hardly pay to grind or crush oats. They should be thus prepared, however, for horses with poor teeth, for foals, and often for hard-worked horses. New or musty oats should be avoided. A safe rule is to feed 1 quart or 1 pound of oats daily for each 100 lbs. of horse—more for the hard-worked and less for the idle.

Even oats do not always form a perfect concentrate, for Axe[3] states that the strongest advocates of this feed in England recognize that for hunters and for other horses in severe weather the ration is improved by the addition of beans.

474. Substitutes for oats.—Because of their universal favor and the wide demand for them, oats are rarely an economical grain where expense must be considered. Fortunately, both practical and scientific trials alike teach that other single grains or mixtures of concentrates may be substituted for oats without injury to the condition, wind, endurance, or even the spirit of the horse.

The Arab steed, so renowned for mettle and endurance, is fed no oats, but chiefly barley. After experiments covering 35 years, involving the feeding of 16,000 omnibus horses in Paris and some 17,000 French army horses, Lavalard,[4] the great French authority on the nutrition of the horse, concluded that the substitution of other feeds for oats, while effecting a great saving, had not in the slightest lowered the productive power of the horses.

The entire success attained with grain mixtures containing no oats, but properly balanced in nutrients and having the requisite bulk, shows that in making up the ration for the horse, just as with other animals, the prices of the various available feeds should always be considered. The many grains and by-products which may be successfully fed to the horse in place of oats are discussed in the following articles. From these studies and a knowledge of ruling market prices for feeds each feeder may determine for himself the most economical rations to employ.

475. Indian corn.—Next to oats, Indian corn (maize) is the common grain for horses in America, being most largely used in the middle and southern portions of the corn belt and southward in the cotton states. Millions of horses and mules on American farms and plantations get their strength from corn, scarcely knowing the taste of oats. While corn does not have all of the superlative qualities of oats, nevertheless, because of lower cost and higher feeding value, it will always be extensively used in this country wherever large numbers of horses must be economically maintained. (201)

When corn forms a large part of the concentrate allowance, the ration should be balanced by concentrates or roughages rich in protein and mineral matter, in which this grain is deficient. As corn is a heavy, highly concentrated feed, care must also be exercised in limiting the amount fed to the needs of the animal. To neglect of these principles may be as-

[3] The Horse, etc., 1907, Vol. 8, p. 347. [4] Expt. Sta. Rec., 12, 1900, p. 13.

cribed the unfavorable results that sometimes follow the feeding of this grain.

In all cases changes from oats or other feeds to corn should be brought about gradually. New corn may produce indigestion. Ear corn is safer to feed than shelled corn, for the grain keeps best on the cob and the horse eats corn on the cob more slowly and chews the grain more completely. Unfortunately it is often difficult to secure good ear corn in the city, due to its bulk.

Altho thruout the corn belt the grain is usually fed on the cob or shelled, various authorities[5] recommend grinding, especially for hard-worked horses. Finely ground corn meal fed alone, however, may form an adhesive mass in the stomach, difficult to digest, and cause colic. If it cannot be fed on the cob it is safer to grind coarsely, or if fine, it should be mixed with chaffed hay or straw. The Paris Omnibus Company[6] found it advantageous to feed corn-and-cob meal, holding that the fiber of the cobs made the ground material more like ground oats in fiber content. In experiments at the North Carolina Station[7] with 3 teams of mules and 1 team of horses Burkett found corn-and-cob meal as valuable as an equal weight of shelled corn. The economy of grinding corn will depend on the cost and trouble involved; generally it will not pay. (**423**)

476. Corn with carbonaceous hay.—Since a ration composed of corn and carbonaceous roughage, as timothy or prairie hay, is deficient in protein, even for work animals, it will be improved by the addition of some nitrogenous concentrate. This is shown by the following results secured by McCampbell at the Kansas Station[8] in a 140-day trial with artillery horses, performing more severe labor than the average farm horse:

Feeding a nitrogenous supplement with corn and carbonaceous hay

Average ration	Initial weight	Gain or loss in weight	Nutritive ratio	Daily cost of feed per 1,000 lbs. live wt.*
	Lbs.	Lbs.		Cents
Lot I, 76 horses				
Oats, 12 lbs.				
Prairie hay, 14 lbs.	1,131	16.3	1 : 7.9	20.3
Lot II, 76 horses				
Shelled corn, 12 lbs.				
Prairie hay, 14 lbs.	1,181	—29.3	1 : 11.5	17.5
Lot III, 22 horses				
Shelled corn, 6 lbs.				
Wheat bran, 3 lbs.				
Linseed meal, 1 lb.				
Prairie hay, 14 lbs.	1,159	3.9	1 : 8.4	16.7

* Oats, $0.385 and shelled corn, $0.55 per bu.; wheat bran, $20.00, linseed meal, $35.50, and prairie hay, $12.50 per ton.

In the winter when the weather was cold and the work moderate there was no apparent difference between the horses in Lots I and II. However, as the weather grew warmer and the work more severe, the corn-fed horses began to lose weight, tho their endurance, wind, or spirit was not

[5] Stewart, Feeding Animals, 1886, p. 384; Burkett, Farm Stock, 1909, p. 72.
[6] Centbl. Agr. Chem., 1881, p. 767. [7] N. C. Bul. 189. [8] Kan. Bul. 186.

injured. The well-balanced ration fed Lot III was fully as satisfactory as the oat ration and more economical than the straight corn ration. The objections often raised against corn—that horses fed corn lack nerve and action, sweat easily, and wear out earlier—are doubtless due to feeding an excess of this grain or failure to balance the ration properly.

Hooper and Anderson of the Kentucky Station[9] report that corn with timothy and oat hay maintained mules, working on an average 6 hours a day, in good condition, but that the skin and hair of the corn-fed mules were not so soft and glossy as with those fed a mixture of 3 parts corn, 1 part wheat bran, and 1 part oil meal.

Beginning in 1874, the Paris Omnibus Company, employing nearly 10,000 horses averaging about 1200 lbs. each, conducted extensive feeding trials with Indian corn. Feeding corn exclusively with hay from the grasses was found to depress the spirits of the horses, and accordingly a mixture of 6.6 lbs. of corn and 12.1 lbs. of oats was adopted, varying somewhat with different horses. Lavalard[10] states that thru this combination the company effected a saving of from $200,000 to $300,000 yearly. The Paris Cab Company, also beginning at about the same time to feed corn in place of oats, had such satisfactory results that it almost entirely ceased feeding oats.

From these trials, and others with some 17,000 French army horses, Lavalard writes: "Experiments have demonstrated that corn can replace oats in the ration of both army and cavalry horses, and if substituted weight for weight, it increases the nutritive value of the ration. . . . . The horses fed the corn ration were used the same number of hours in military drill, and in the maneuvers were ridden at the same gait as those fed oats, and it was practically impossible to perceive the least difference in the 2 classes. The army officers, prejudiced as they naturally were, were forced to admit that all the horses showed the same energy and vigor. Careful records kept show that sickness and mortality were the same for the horses on the 2 rations."

477. Corn and legume hay.—With legume hay, which supplies the lacking protein and ash, for roughage, corn may be successfully fed as the only concentrate to mature horses at general farm work. Carmichael fed one horse in each of 3 farm teams at the Ohio Station[11] ear corn, and the other one oats with mixed clover and timothy hay for roughage. The trial lasted 48 weeks, with the following results:

Ear corn vs. oats with mixed clover and timothy hay

Average ration	Initial weight Lbs.	Gain or loss in weight Lbs.	Work per day Hrs.	Daily cost of feed* Cents	Feed cost per hour of work* Cents
Corn-fed horses					
Ear corn, 14.9 lbs.					
Mixed hay, 16.0 lbs....	1,525	—3	5.4	15.0	3.3
Oat-fed horses					
Oats, 14.8 lbs.					
Mixed hay, 17.3 lbs....	1,424	9	5.3	20.8	4.5

* Corn, $0.40, and oats, $0.30 per bu.; hay $8.00 per ton.

[9] Ky. Bul. 176, 1913. [10] Expt. Sta. Rec., 12, 1900, p. 14. [11] Ohio Bul. 195.

The corn-fed horses received about the same weight of ear corn, including cob, as their team mates did of oats, and ate less hay, yet they practically maintained their weight. Substituting ear corn for oats resulted in a saving of over one-fourth in cost of feed.

Trowbridge fed one mule in each of 2 farm teams at the Missouri Station[12] shelled corn and the other one oats, all receiving mixed clover and timothy hay, for 364 days, when the rations were reversed and the feeding continued for another 364-day period. The mules fed corn maintained their weight slightly better than those fed oats and at 21 per ct. less expense for feed, with oats at $0.40 and shelled corn at $0.50 per bushel. Both Carmichael and Trowbridge report that the corn-fed animals endured hard work during hot weather as well as those fed oats, and that the corn was not detrimental to health or spirit.

478. Barley.—This grain is extensively employed for horse feeding in Africa, in various parts of the Orient, and in Europe. In this country it is used on the Pacific coast, especially in California. Shepperd of the North Dakota Station[13] found that for hard-worked horses barley was not quite so valuable, pound for pound, as oats. Lavalard also concludes from 20 years' experience that to replace oats a slightly greater quantity of barley must be fed, especially when rations are calculated as closely as they are with army horses. Where the horses' teeth are good and their labor not severe, barley may be fed whole, but it is usually best to grind or, better, roll it. Barley meal forms a pasty, unpleasant mass when mixed with the saliva in the mouth. This can be largely avoided by crushing the grain to flattened discs between iron rollers. (226)

479. Wheat.—Altho the price of sound wheat usually prohibits its use as a horse feed, that which has been frosted or otherwise damaged, if not moldy, may be fed with economy. Wheat should preferably be rolled and fed in moderate amounts only, mixed with a bulky concentrate, such as bran, or with chaffed forage to avoid digestive troubles and skin eruptions.[14] (215)

480. Rye.—In Germany, according to Pott,[15] many work horses are fed 2 to 6.6 lbs. of rye per day in combination with oats or other concentrates, the grain preferably being rolled or bruised and mixed with cut straw. The change to rye must be gradual or colic may result, especially if the grain is not well mixed with cut fodder. The bad results reported with rye are probably due to grain of poor quality, or that containing impurities. (232)

481. Kafir; milo.—In the regions where they flourish, the seeds of the various sorghums are extensively employed for horse feeding, tho somewhat less valuable than corn. Being small and hard, they should be ground or chopped, and if possible mixed with bran or middlings, for they tend to produce constipation. These grains may also be fed un-

[12] Mo. Bul. 114.
[13] N. D. Bul. 45.
[14] Shepperd, N. D. Bul. 45; Pott, Handb. Ernähr. u. Futter., II, 1907, p. 445.
[15] Handb. Ernähr. u. Futter., II, 1907, p. 449.

threshed in the heads along with the forage. Morrow of the Oklahoma Station[16] reports the successful feeding of kafir to farm mules and horses. (235–42)

482. Cane molasses.—Thruout the sugar-cane districts cane molasses is often the most economical source of carbohydrates for work animals. Dalrymple[17] of the Louisiana Station, collecting data from 47 Louisiana sugar plantations employing over 5,000 work animals, chiefly mules, found that an average of 9.5 lbs. of cane molasses was fed daily to each animal, the maximum being 21 lbs. The molasses was usually mixed with corn (ground with both cob and husks), other concentrates, or cut hay, but was sometimes fed separately in troughs or poured on uncut roughage. The ration was usually balanced with legume hay or cottonseed meal. Planters held that the use of molasses reduced digestive disturbances and improved the health and endurance of the animals, with a saving of 10 to 50 per ct. in cost of feed. No scouring, such as would be produced by large quantities of beet molasses, was noted. Berns[18] reports improvement in the condition of 100 heavy truck horses in New York on feeding 1 quart of molasses daily, diluted with water and mixed with grain and cut hay. Dalrymple and Berns both obtained satisfactory results on feeding molasses to driving horses.

Because of its high price molasses is rarely an economical source of carbohydrates in the northern states, tho a quart or more a day may often be profitable as an appetizer or tonic with horses out of condition.[19] (279)

483. Beet molasses and molasses mixtures.—Because of its laxative properties, beet molasses must be fed only in limited amounts, but when not given in excess, it has given satisfactory results and is well liked by horses. (276) It may be thinned with warm water and mixed with cut fodder or fed in such mixtures as molasses-beet-pulp, alfalmo, etc. (280) In trials with 130 hard-worked horses of a Budapest transportation company, Weiser and Zaitschek[20] obtained entirely satisfactory results for months with a ration, per 1000 lbs. live weight, of 4.1 lbs. beet molasses mixed with 5.6 lbs. wheat bran and fed with 5.7 lbs. corn with an unlimited allowance of hay. One lb. of molasses replaced 0.78 lb. of corn. When the molasses was increased to 5.5 lbs. per 1000 lbs. live weight no injurious effect on the health of the animals was observed, but the molasses-bran mixture proved too sticky to be palatable. Pott[21] mentions the successful use of various molasses mixtures and cites instances where 2 to 3 lbs. of peat-molasses successfully replaced an equal weight of grain.

[16] Okla. Rpt. 1898.
[17] La. Bul. 86, 1906; Breeder's Gaz., 48, 1905, p. 277.
[18] Amer. Vet. Rev., 26, 1902, pp. 615–623.
[19] Lindsey, Mass. Bul. 118, 1907; Gay, Productive Horse Husbandry, 1914, p. 238.
[20] Landw. Jahrb., 37, 1908, pp. 138-149.
[21] Handb. Ernähr. u. Futter., III, 1909, p. 336.

In trials with 15,000 horses of the Paris Omnibus Company Lavalard[22] fed as high as 4.4 lbs. of peat-molasses daily with fewer digestive disturbances than on a ration containing no molasses.

Molasses and many of the molasses mixtures on the market are carbonaceous feeds, deficient in protein, and at the high prices often asked are uneconomical sources of carbohydrates.

484. Miscellaneous carbonaceous concentrates.—*Sugar,* fed in small amounts, has been recommended for horses. On feeding one lot of 18 artillery horses oats and prairie hay and another lot the same ration, except that 0.5 lb. of sugar was substituted for 2 lbs. of oats, McCampbell[23] of the Kansas Station found that the sugar-fed horses sweat more easily than the others, altho showing excellent coats of hair and good appetites. He concludes that while a small amount of sugar may be fed as a conditioner, it is not an economical substitute for the various grains ordinarily available. (**281**)

Rough rice is an economical feed for horses and mules in the southern states, when low in price compared with other cereals. In trials with 2 mules at the Louisiana Station Dalrymple[24] gradually substituted rough rice for an equal weight of cracked corn, feeding as high as 8 lbs. per day with good results. (**234**)

Dried beet pulp is often refused by horses when fed alone, but when mixed with other concentrates may well be used as a portion of the ration. In Hanover, Germany, 5.5 to 6.6 lbs. per head daily are often fed to work horses.[25] (**275**)

II. Nitrogenous Concentrates

485. Leguminous seeds.—Like the horse bean and other varieties of beans, so widely fed in Europe, the field pea in the northern states and the cowpea and soybean farther south are useful in supplementing rations deficient in protein. (**256, 261–2**) At the North Carolina Station[26] Burkett obtained satisfactory results in feeding cowpea meal as one-third to two-thirds the grain allowance for mules getting corn-and-cob meal and meadow or oat hay. All these leguminous seeds should be ground, and on account of their protein-rich nature should not be fed as the sole concentrate. Lavalard[27] states that when beans replace oats only half the quantity should be used.

486. Wheat bran.—Bran is one of the most useful feeds for the horse, because of its bulky nature and mild laxative properties. (**218**) If not more freely provided, its use once a week, preferably in the form of a

[22] Deutsche Landw. Tierzucht, 1902, p. 986.
[23] Kan. Bul. 186, 1912.
[24] La. Bul. 122.
[25] Pott, Handb. Ernähr. u. Futter., III, 1909, p. 310.
[26] N. C. Bul. 189.
[27] Expt. Sta. Rec., 12, 1900, p. 15.

mash, wet or steamed, is desirable for its beneficial action on the alimentary tract. As the immediate effect of the laxative mash is somewhat weakening[28] it should be given at night and preferably before a day of rest.

When low in price, bran may profitably be fed in larger amounts as a partial substitute for oats. Burkett fed 2 1220-lb. farm work horses a ration of 7 lbs. of oats and 7 lbs. of corn with 12 lbs. of timothy hay during the summer at the New Hampshire Station,[29] while in the ration of 2 others 7 lbs. of bran was substituted for the oats. The horses fed bran worked on the average 0.7 hour less per day than those fed oats but made an average gain of 113 lbs. during 26 weeks, while the oat-fed horses gained only 28 lbs. After repeating the trial during the winter with substantially the same results, Burkett concludes that when fed in this combination bran can replace an equal weight of oats. As bran is low in lime, when heavy allowances of bran are used feeds should be given which are high in lime, or lime should be added in the form of ground limestone, etc. (**98**) After years of experience Shepperd of the North Dakota Station[30] concludes that a mixture of equal parts by weight of bran and shorts, fed with prairie hay, is equal to the same weight of oats for farm work horses, tho not quite so palatable. Pott[31] holds that feeding over 1 lb. of bran per day to horses worked at a rapid pace tends to make them indolent.

487. Wheat middlings; shorts.—Tho furnishing more nutriment than bran, middlings or shorts are not as desirable for the horse, because of their heavier character. When fed to horses they should be mixed with bulky feed and given in relatively small amount, as they tend to produce colic, the danger being great with some horses. (**220**)

488. Dried brewers' grains.—This by-product may often be substituted for oats with economy. At the New Jersey Station[32] in a trial with 4 teams of 1000-lb. street car horses, fed a ration of 8 lbs. oats, 2 lbs. wheat bran, 4 lbs. shelled corn, and 6 lbs. hay, Voorhees substituted an equal weight of dried brewers' grains for the oats in the ration of one horse in each team. The change produced no ill effects on the horses, which traveled not less than 24 miles per day. The conclusion was reached that pound for pound good quality dried brewers' grains were fully equal to oats. Voorhees reports[33] that a gardener living near the Station, guided by its teachings, successfully fed a ration of dried brewers' grains, corn, and hay to 8 animals, with a saving in yearly feed bills of about $150 over the previous cost. Not being particularly palatable, dried brewers' grains should be mixed with other concentrates. Hooper and Anderson[34] of the Kentucky Station report the grains somewhat constipating for horses and mules. (**228**)

[28] Burkett, Farm Stock, 1909, p. 73.
[29] N. H. Bul. 82.
[30] N. D. Bul. 45.
[31] Handb. Ernähr. u. Futter., III, 1909, p. 159.
[32] N. J. Rpt. 1892.
[33] N. J. Rpt. 1893.
[34] Ky. Bul. 176.

489. Linseed oil meal or cake.—Linseed meal, with its high protein content and its tonic and somewhat laxative properties, is an excellent nitrogenous supplement for the horse. McCampbell of the Kansas Station[35] compared the value of linseed meal and wheat bran in a 110-day trial in which 1170-lb. artillery horses were fed a ration of 12 lbs. prairie hay, 4 lbs. oats, 6 lbs. corn, and either linseed meal or wheat bran, as shown in the table:

Linseed meal vs. wheat bran for horses

Daily supplement allowance	Av. loss in wt. per head Lbs.	Daily cost per 1,000 lbs. live wt. Cents
Lot I, 77 horses, Linseed meal, 1 lb.	2.5	17.0
Lot II, 75 horses, Wheat bran, 4 lbs.	6.7	18.8

In this trial 1 lb. of linseed meal was as effective in balancing the ration as 4 lbs. of bran, for the horses in Lot I lost slightly less in weight than those in Lot II and showed better coats of hair, indicating a thriftier condition. The endurance and spirit of both lots were entirely satisfactory. With linseed meal at $35.50 and bran at $20.00 per ton, the substitution of the meal lowered the feed bill about 10 per ct.

In a trial at the Iowa Station[36] with 3 teams of farm horses Kennedy, Robbins, and Kildee found a mixture of 1 part oil meal and 10 parts shelled corn, fed with timothy hay, too laxative for horses at hard work in summer. A mixture of 1 part oil meal, 4 parts oats and 12 parts corn, proved as satisfactory as one of 6 parts oats and 4 parts corn. Substituting oil meal for a large part of the oats saved 1.6 cents in daily cost of feed. Altho Pott[37] reports the satisfactory use with work horses of 3 to 4 lbs. of linseed cake in combination with other feeds, not over 1 to 1.5 lbs. per head daily should ordinarily be given. A pound or less a day of linseed meal is a helpful conditioner for run-down horses with rough coats, and is excellent in spring to hasten shedding of the hair and as a laxative with constipated animals. In fitting horses for show or sale it gives bloom and finish. (**254**)

490. Cottonseed meal.—While it is not safe to feed cottonseed meal in large amounts to horses or mules, good results are secured when this feed is properly used. Being a heavy concentrate, not particularly relished by these animals, it should be mixed with some well-liked bulky feed. At the North Carolina Station[38] Curtis found it impracticable to feed mules on cottonseed meal and ear corn. Altho fairly satisfactory, a mixture of 1 part cottonseed meal with 6 parts shelled corn was less relished than 1 part of meal with 3 of corn-and-cob meal, the remaining corn being fed on the cob. The meal may also be mixed with whole or crushed oats, dried brewers' grains, or cut hay. It is claimed by some that crushed or ground unhusked corn gives excellent results as a basal feed when using cotton-

[35] Kan. Bul. 186.
[36] Iowa Bul. 109.
[37] Handb. Ernähr. u. Futter., III, 1909, p. 25.
[38] N. C. Buls. 215, 216.

seed meal. Burkett[39] suggests sprinkling the meal on silage, or on hay or stover moistened previous to feeding. Louisiana planters attribute their success in feeding cottonseed meal largely to the fact that they mix it with blackstrap molasses.

Curtis states that the meal fed daily should rarely exceed 2 lbs. per animal, a safe rule being 0.2 lb. for every 100 lbs. live weight of animal. For work horses the cottonseed meal fed should not exceed 15 or, better, 10 per ct. of the total ration by weight. Horses should be started on cottonseed meal gradually, not over one-fourth lb. being given at each feed for the first 2 or 3 weeks. When the maximum amount of meal is fed it should be distributed equally in the 3 daily feeds. Against the claim that work stock fed on cottonseed meal suffer from short wind and weak eyes, Curtis reports that trials covering 3 years showed no such harmful effects. Judge Henry C. Hammond of Augusta, Georgia,[40] reports that for 5 years he fed 10 pleasure and work horses each 1 lb. of cottonseed meal daily without a single sick animal or one not ready for work, due, he holds, to the fact that the meal was always mixed with some light concentrate.

In a 154-day test at the Iowa Station[41] with 3 work teams fed timothy hay, 6 per ct. of cottonseed meal proved as effective as 8 per ct. of linseed meal in balancing a grain mixture of 15 per ct. oats and the remainder corn. Burkett[42] found a ration of cottonseed meal, corn, and corn stover satisfactory in winter for horses and mules doing moderate work. Like linseed meal, cottonseed meal is useful in conditioning horses and improving their coats.[43] (**246–50**)

491. Miscellaneous nitrogenous concentrates.—*Oil cakes and meals* from sunflower seed, rape seed, peanut, cocoanut, sesame, etc., are fed to horses in different parts of Europe in quantities of 2.2 to 4.4 lbs. per horse daily with good results.[44] The French war department[45] found cocoanut meal equal to the same weight of oats for army horses. (**258-60**)

Gluten meal was found by Kennedy, Robbins, and Kildee at the Iowa Station[46] to be rather unpalatable when 1 part was fed with 8 of corn meal, altho this mixture fed with timothy hay maintained the weight of farm horses as well as a mixture of 1 part linseed meal and 15 of corn. (**211**)

Dried distillers' grains fed by Lindsey[47] at the Massachusetts Station as one-fourth of the concentrate allowance to horses gave excellent results. Fed by Plumb[48] at the Indiana Station as one-third of the grain allowance, these proved fairly satisfactory with some horses, but unpalatable to others. (**282**)

[39] N. C. Bul. 189.
[40] Pamphlet "Cottonseed Meal for Horses and Mules"; private correspondence.
[41] Iowa Bul. 109.
[42] N. C. Bul. 189.
[43] Curtis, N. C. Bul. 215, 1911; Pott, Handb. Ernähr. u. Futter., III, 1909, p. 110.
[44] Kellner, Ernähr. Landw. Nutztiere, 1907, p. 456.
[45] Milch Zeit., 1883, p. 517. [46] Iowa Bul. 109. [47] Mass. Bul. 99. [48] Ind. Bul. 97.

Tankage and blood meal were found by Burkett at the North Carolina Station[49] to be useful for run-down, thin horses, 1 to 2 lbs. of tankage or 1 lb. of blood meal being employed. Pott[50] states that blood meal has given excellent results in horse feeding. La Querriere[51] states that boiled meat meal mixed with hay and straw is excellent for horses. The Arabs feed their horses camel's flesh mixed with other feed in the form of cakes. (**270**)

III. Carbonaceous Roughages

492. Excess of roughage injurious.—We have seen previously that horses can not live on concentrates alone, even on oats with their straw-like hulls. (**107**) An excess of roughage, on the other hand, is also injurious. When we recall that the stomach of the horse has a capacity of only 19 quarts (**35**), while the 4 stomachs of a cow may hold 267 quarts, it is evident that the horse at hard work cannot well derive most of its nourishment from roughage. Thru carelessness or mistaken kindness the mangers are often kept filled with hay, especially in the case of farm horses. The horse then gorges himself on this provender, with a staring coat, labored breathing, and quick tiring as the least serious, tho probably the most noticeable results. For this animal there should always be a definite, limited daily allowance of hay, given mostly at night when there is ample time for its mastication and digestion. Many digestive disturbances are caused by forcing the horse to work with his stomach distended by coarse feed. More horses are injured by feeding too much than too little hay. On feeding 1 horse in each of 2 teams doing ordinary farm work all the timothy hay they would eat, in addition to oats, while the others were given about two-thirds as much hay, Clark[52] at the Montana Station found that those fed the smaller amount had more life and sweat less. In another trial a horse receiving 7.5 lbs. of grain daily was allowed all the early cut timothy hay it wished, and ate so much that it failed to gain in weight, had a staring coat, and lacked life and vigor.

493. Timothy hay.—Altho not rich in digestible nutrients, timothy hay is the standard roughage for the horse thruout the northeastern United States. The freedom from dust of good timothy hay commends it as a horse feed, and it is an excellent roughage for animals whose sustenance comes mostly from concentrates. While timothy cut too green makes "washy" hay, it should not be allowed to stand until it becomes woody and indigestible. A reasonable allowance of timothy hay is 1 lb. daily per 100 lbs. of animal. So far as possible the other roughages here considered will be compared with timothy hay as the standard. (**312**)

494. Cereal hay.—On the Pacific coast, especially in California, the cereal hays—barley, wild oat, wheat, etc.—are extensively employed as roughages for horses. The excellence of the speed horse and the endurance of the work horse of the coast region attest the merits of these feeds.

[49] N. C. Bul. 189.
[50] Handb. Ernähr. u. Futter., III, 1909, p. 515.
[51] Milchzeitung, 1881, p. 753.
[52] Mont. Bul. 95, 1913.

In some cases where racing horses have been sent to the East cereal hay was forwarded with them for their nourishment. Thruout the Rocky Mountain region oat hay is of considerable importance. Cereal hay may often be advantageously employed for horse feeding in the eastern United States. At the North Carolina Station[53] Burkett found that hay from oats cut in the milk stage compared favorably with clover and cowpea hay for horses. (**318**)

495. Prairie hay.—Thruout the western states prairie hay from the wild grasses forms an excellent roughage for the horse. From trials lasting 110 to 140 days with 453 artillery horses, McCampbell[54] of the Kansas Station concludes that timothy hay is slightly more valuable than prairie hay, since the horses fed timothy maintained their weight rather better than those fed prairie hay. However, he holds that when timothy hay costs 10 per ct. more than good prairie hay, the latter is more economical. (**325**)

496. Brome hay.—This hay, common to the northern plains region, proved fully equal to timothy in a trial at the North Dakota Station in which Shepperd[55] fed 1 horse in each of 2 work teams brome hay and oats, while their team mates received timothy and oats, as the following shows:

Brome vs. timothy hay for horses

Average ration	Daily gain in weight Lbs.	Daily work Hours
Lot I, Brome hay, 22.2 lbs. Oats, 14.5 lbs.	0.77	5.2
Lot II, Timothy hay, 21.9 lbs. Oats, 14.5 lbs.	0.42	5.2

The horses getting brome hay gained slightly more in weight than those fed timothy. (**316**)

497. Southern hays.—To determine the value of Johnson grass, Bermuda, and lespedeza hay compared with timothy or alfalfa hay Lloyd of the Mississippi Station[56] conducted trials with 5 lots of 4 to 5 growing 2- to 3-yr.-old mules for 89 days, the animals being fed under shelter and allowed the freedom of a yard. The mules in each lot were given a grain allowance of 2 lbs. oats, 4 lbs. corn-and-cob meal, and 0.5 lb. cottonseed meal, with hay as shown in the table:

Comparison of southern hays

Average allowance of hay	Av. daily gain Lbs.	Feed per 100 lbs. gain: Concentrates Lbs.	Feed per 100 lbs. gain: Hay Lbs.	Cost per lb. gain Cents*
Lot I, Johnson grass hay, 11.3 lbs.	0.44	1,558	2,520	36
Lot II, Bermuda hay, 11.3 lbs.	0.43	1,607	2,601	37
Lot III, Timothy hay, 11.3 lbs.	0.44	1,573	2,545	48
Lot IV, Lespedeza hay, 11.3 lbs.	0.67	1,038	1,680	27
Lot V, Alfalfa hay, 11.3 lbs.	0.86	812	1,313	21

* Johnson grass and Bermuda hay $11, timothy hay $20, and lespedeza and alfalfa hay $15 per ton.

This trial shows that hay from Johnson or Bermuda grass is as valuable for horses or mules as timothy hay. (**320–1**) Lespedeza and alfalfa

[53] N. C. Bul. 189.
[54] Kan. Bul. 186.
[55] N. D. Bul. 45.
[56] Information to the authors.

hay are of still higher value for growing animals on account of their richness in protein and ash. With lespedeza and alfalfa hay at $15 per ton and Johnson grass and Bermuda hay at $11, the legume hays produced gains at a considerably lower cost.

498. Millet hay.—Hay from Hungarian grass, Japanese millet, etc., may often be advantageously fed to horses, provided the allowance is limited. Hinebauch of the North Dakota Station[57] found that, fed exclusively to horses for long periods, millet hay caused increased action of the kidneys, lameness and swelling of the joints, infusion of the blood into the joints and finally destruction of the texture of the bones, which were rendered soft and less tenacious so that movements of the animal would sometimes cause the ligaments and muscles to be torn from them. Since the millets are among the oldest and most widely grown of all agricultural plants, it is but fair to hold that good millet hay, fed in moderation, or with other roughage and always with some concentrate, should prove satisfactory and produce no unfavorable effects. (**317**)

499. Sorghum hay.—Forage from the sweet sorghums, when properly cured, is superior to corn forage for horses. It usually deteriorates rapidly in value after midwinter unless well cured and kept in a dry place. Moldy, decaying sorghum forage is especially dangerous to horses. Kafir, tho not quite so palatable as the sweet sorghums, is extensively and profitably used for horse feeding over a large region in the southwestern states. The Oklahoma Station[58] found kafir stover equal to corn stover in feeding value. (**308**)

500. Corn fodder and corn stover.—Thickly grown fodder corn and corn stover, when properly cured and cared for, are among the best of roughages for the horse. Corn leaves are usually quite free from dust, palatable, and full of nutriment. For stallions, brood mares, idle horses, and growing colts good corn forage is usually a most economical and helpful substitute for timothy hay. When the yield of fodder corn and its feeding value are compared with that of the timothy hay from a like area, the usefulness and economy of this much neglected forage is apparent. The cured corn plant should be much more generally used in America for horse feeding than it now is. (**294–7**)

That the entire roughage fed farm horses during the winter when at light work may advantageously consist of corn stover is shown in a trial by Burkett at the New Hampshire Station[59] with 2 lots each of two 1225-lb. farm horses fed the following rations for 73 days from January to April.

Corn stover vs. timothy hay for horses

Average ration				Average gain Lbs.	Av. work per day Hours
Lot I,	Corn stover, 12 lbs.	Corn, 7 lbs.	Oats or bran, 7 lbs...	3	3.4
Lot II,	Timothy hay, 12 lbs.	Corn, 7 lbs.	Oats or bran, 7 lbs...	18	3.3

[57] N. D. Bul. 26. [58] Okla. Rpt. 1899. [59] N. H. Bul. 82.

Since the stover-fed horses did a little more work than the others and gained but slightly less, cut corn stover may be regarded as equal to timothy hay in this trial. With timothy hay usually selling for 2 to 4 times as much as stover, the great economy of the latter is apparent.

501. Straw.—Straw contains much fiber and its mastication and digestion by the horse call for a large amount of energy, which appears as heat, thereby warming the body tho not producing useful work. (78–80) Because of this, horses doing little or no work in winter and having ample time for chewing and digesting their feed may often be profitably wintered largely on bright straw. Many horses are fed costly hay in winter when straw, corn fodder, or corn stover would prove satisfactory and much cheaper. In Europe nearly all rations for horses contain straw, those hardest worked receiving the least. In feeding value the straws rank in the following order: oat, barley, wheat, rye, the last-named having but slight value. Farm horses should not be wintered in the barnyard on straw and corn stover only, without any grain, for they will not be in condition to endure the severe labor upon the sudden opening up of work in the spring. (328–9)

502. Corn stover and straw reduce feed bills.—The saving which may be made thru the use of such cheap roughages as corn stover and straw in place of a large part of the timothy hay, and of substitutes for oats is well illustrated in a trial by Norton at the Michigan Station[60] in which 2 lots, each of 6 farm horses doing moderate work, were fed the following rations for 10 weeks in winter: Lot I was fed exclusively on high-priced timothy hay and oats (with a light feed of bran once a week), while in the ration fed Lot II shredded corn stover and oat straw were substituted for a large part of the timothy hay, and roots, ear corn, and a mixture of equal parts of bran, dried beet pulp, and linseed oil cake for most of the oats.

Lessening cost of feed by use of corn stover and straw

Feeding stuff	Price per ton Dollars	Amount fed per day Pounds	Cost of feed per day Cents
Lot I			
Timothy	12.00	20.4	
Oats	31.00	11.0	29.6
Lot II			
Shredded corn stover	4.00	8.6	
Oat straw	5.00	4.3	
Timothy hay	12.00	4.2	
Carrots	3.00	5.4	
Ear corn	20.00	4.2	
Oats	31.00	3.1	
Feed mixture	21.00	2.6	17.7

During the trial the horses in Lot I, fed the ration of timothy hay and oats, costing 29.6 cents a day, each lost an average of 11 lbs. in weight.

[60] Mich. Bul. 254.

On the other hand those getting the cheaper but well-balanced ration gained 14 lbs. each at a feed cost of 17.7 cents per day—a saving of 40 per ct.

503. Carbonaceous roughages require supplement.—It should be remembered that hay from the grasses, corn fodder, corn stover, sorghum and kafir forages, and straw are all low in protein. Therefore, when these roughages are used exclusively, protein-rich concentrates should be fed to balance the ration. This fact, which has already been brought out (476), is also shown in other trials by McCampbell[61] in which horses fed corn and prairie hay only did not thrive as well as others fed corn and oats, or corn, bran, and linseed meal with the prairie hay.

IV. Legume Hay

504. Legume hay.—Properly cured hay from the legumes is usually more palatable to horses than other roughage; hence if they are allowed to eat at will, there is even greater danger of their consuming an excess than with hay from the grasses. Numerous experiments show that to maintain the weight of horses it is not necessary to feed as great a weight of the legume hays, which are more like concentrates in their nature. These protein-rich hays are admirably suited to balance corn or other concentrates low in protein. As the legumes are more difficult to cure than the grasses, there is more danger of hay from them being loaded with dust or otherwise damaged in quality. The prejudice against legume hay for horse feeding, so frequently encountered, is largely due to the fact that these rich roughages have been given in excess or that hay of poor quality has been used.

505. Clover hay.—Because clover hay is often carelessly made and loaded with dust, thereby tending to produce heaves, it is disliked by many horsemen, particularly for feeding roadsters. This objection, however, should not apply to clean, properly-cured clover hay. Roberts[62] suggests that for driving horses clover hay be mixed with bright straw and the mass dampened; this forms a satisfactory roughage for all but fast drivers. Gay advises the use of mixed clover and timothy hay instead of clover alone.[63] For horses at ordinary farm work, clover is often used as the sole roughage. Terry,[64] the conservative, reliable farmer-writer, kept a medium-weight farm work team for a number of years in prime condition solely on well-made clover hay. To compare the value of clover and timothy hay, Obrecht[65] fed 1 horse in each of 6 teams of 1400-lb. farm horses at the Illinois Station clover hay with the grain allowance shown on the next page, while its team mate was fed timothy hay with the same grain allowance. After 196 days the rations were reversed and the trial continued for 20 weeks.

[61] Kan. Bul. 186.
[62] The Horse, p. 282.
[63] Productive Horse Husbandry, 1914, p. 240.
[64] Our Farming, p. 137.
[65] Ill. Bul. 150.

Clover vs. timothy hay for horses

Average ration	Gain in weight Lbs.	Daily work Hours
Clover-fed horses		
Corn, 6.9 lbs. Oats, 7.3 lbs.		
Oil meal, 0.46 lb. Bran, 0.61 lb.		
Clover hay, 15.6 lbs.	15.5	7.3
Timothy-fed horses		
Corn, 6.8 lbs. Oats, 7.2 lbs.		
Oil meal, 0.53 lb. Bran, 0.60 lb.		
Timothy hay, 15.6 lbs.	3.0	7.3

Altho most of the teamsters were prejudiced in favor of timothy hay at the beginning, they later reported that they could observe no difference in the spirit of the horses or their ability to endure hot weather. The horses fed clover hay had glossier coats and their bowels were looser, but not objectionably so for doing hard work. (**347**)

Wilcox and Smith[66] state that second-crop clover hay is frequently accused of causing slobbering. The reason is unknown, but some horsemen state that the addition of bran or apples to the ration tends to prevent the trouble.

506. Alfalfa hay.—Because it is cheap and abundant this legume hay furnishes the sole roughage for horses upon tens of thousands of farms and ranches in the West. With the increasing culture of alfalfa in other sections of the country more and more alfalfa hay is likewise being fed to horses in these districts. It is therefore important to learn the conditions essential to its successful use. When the horse is allowed to gorge on alfalfa hay, in addition to having his stomach over-distended with the bulky feed he receives an excess of highly nitrogenous material. This must be excreted thru the kidneys, overworking them, and even, according to McCampbell,[67] leading to a chronic inflammatory condition if excessive feeding is long continued. The alfalfa allowance for horses should therefore be limited, McCampbell advising that those at work receive not more than 1.2 lbs. per 100 lbs. live weight. The hay should be free from dust, mold, and smut, and should not be cut until quite mature, for hay from early-cut alfalfa, as commonly advised for cattle, is too "washy" for horses.

In view of the prejudice among liverymen and owners of driving horses against alfalfa, a 140-day trial was conducted by McCampbell[68] with artillery horses, doing more hard work than the average farm team thruout the year, a considerable portion at a trot and no small amount at a gallop. The horses in Lot I were fed alfalfa hay with 2 lbs. oats and 8 lbs. corn, while those in Lots II and III received prairie or timothy hay, with half as much corn and 4 times as much oats.

[66] Farmer's Cyclopedia of Live Stock, 1908, p. 323.

[67] Kan. Bul. 186.

[68] Kan. Bul. 186.

Alfalfa vs. prairie and timothy hay for horses

Average ration	Initial weight Lbs.	Av. gain or loss per head Lbs.	Nutritive ratio	Daily cost of feed per 1,000 lbs. live wt.* Cents
Lot I, 17 horses				
Alfalfa hay, 10 lbs.				
Shelled corn, 8 lbs.				
Oats, 2 lbs.	1,163	25.6	1 : 5.8	12.95
Lot II, 74 horses				
Prairie hay, 14 lbs.				
Corn, 4 lbs.				
Oats, 8 lbs.	1,185	—12.9	1 : 8.9	18.86
Lot III, 76 horses				
Timothy hay, 14 lbs.				
Corn, 4 lbs.				
Oats, 8 lbs.	1,159	— 7.7	1 : 9.0	19.21

*Alfalfa hay, $10; prairie and timothy hay, $12.50 per ton. Corn $0.55 and oats $0.385 per bu.

The alfalfa-fed horses in Lot I, getting 16 per ct. less grain and 28 per ct. less hay than the others, showed no shortness of wind, softness, lack of endurance, or excessive urination. They gained over 25 lbs. each during the trial, while those fed timothy or prairie hay lost in weight.

Obrecht found at the Illinois Station[69] that farm horses fed alfalfa hay when doing hard work maintained their weight on 20 to 22 per ct. less grain than others fed timothy hay. Similar favorable results with alfalfa hay are reported by Merrill[70] (Utah Station), Faville[71] (Wyoming Station), and Gramlich[72] (Nebraska Station). (**339**)

At the Utah Station alfalfa formed the sole roughage for all the work and driving horses for 12 years, except during brief periods when they were on other experimental fodders. During all that time not a horse was lost either directly or indirectly from alfalfa feeding. It was found that horses fed timothy hay voided an average of 16 lbs. each of urine daily, and those on alfalfa 27 lbs., early-cut alfalfa hay causing a greater excretion than late-cut. This increased excretion of urine did not seem to injure the horses in any way.

In the West alfalfa hay, often with straw in unlimited amount, is a common maintenance ration for idle horses. Merrill found 20 lbs. of alfalfa hay sufficient to maintain a 1400-lb. horse when not working, while Emery[73] at the Wyoming Station found that 13.8 lbs. of alfalfa hay and 2.25 lbs. of oat straw would maintain a 1000-lb. idle horse.

507. Alfalfa meal.—To compare the value of alfalfa meal and bran McCampbell[74] fed 2 lots of 1170-lb. artillery horses as shown in the table for 110 days. The data for a third lot of similar horses fed for 140 days on uncut alfalfa hay are included for comparison.

[69] Ill. Bul. 150.
[70] Utah Bul. 77.
[71] Wyo. Bul. 98.
[72] Nebr. Exten. Bul. 28.
[73] Wyo. Rpt. 12.
[74] Kan. Bul. 186.

Alfalfa meal compared with wheat bran and alfalfa hay

Average ration	Gain or loss in weight Lbs.	Daily cost of feed per 1,000 lbs. live wt.* Cents
Alfalfa meal, 152 horses		
Oats, 4 lbs.		
Corn, 6 lbs.		
Alfalfa meal, 4 lbs.		
Prairie or timothy hay, 14 lbs.	— 2.6	17.96
Wheat bran, 151 horses		
Oats, 4 lbs.		
Corn, 6 lbs.		
Bran, 4 lbs.		
Prairie or timothy hay, 14 lbs	— 0.3	18.78
Alfalfa hay, 17 horses		
Oats, 2 lbs.		
Corn, 8 lbs.		
Alfalfa hay, 10 lbs	+25.6	12.95

*Alfalfa meal, $14; alfalfa hay, $10; timothy or prairie hay, $12.50, and bran $20 per ton. Corn $0.55 and oats $0.385 per bu.

For maintaining the weight of the horses a pound of alfalfa meal was practically equal to a pound of wheat bran, when fed in a ration containing 10 lbs. of corn and oats. McCampbell states, however, that alfalfa meal is dusty and disagreeable to handle. If fed dry this dust irritates the air passages of the horse and may cause serious trouble. This objection may be overcome by wetting the meal, which should be done immediately before feeding to avoid souring or molding, but this involves considerable time and inconvenience, especially in winter.

When uncut alfalfa hay constituted the sole roughage the horses maintained their weights better, altho receiving less grain and hay, and the ration was less expensive. McCampbell states that when good quality hay is properly fed, little, if any, is wasted, and concludes that alfalfa meal is neither desirable nor economical when good alfalfa hay is obtainable.

508. Cowpea hay.—In a feeding trial at the North Carolina Station Burkett[75] found that cowpea hay combined with corn-and-cob meal made a satisfactory work ration, and that cowpea hay with a reasonable quantity of corn could be substituted for bran and oats. (**357**)

V. Pasture and Other Succulent Feed

For horses receiving but little exercise succulent feeds are especially beneficial on account of their "cooling" and laxative effect. A limited amount of succulent feed is often employed thruout the year in Europe for work horses and even for drivers.

509. Pasture.—Horses at pasture not only obtain succulent feed, but must exercise to secure it. Good pasture will maintain idle horses satisfactorily; for those at hard work pasture without grain is insufficient. Not only do the various tame and wild grasses furnish pasture for horses, but

[75] N. C. Bul. 189.

as these animals are not subject to bloat, they may graze the legumes as well. City horses are often turned on pasture so that their feet may recover from the ill effects of hard pavements.

510. Corn silage.—Until the past few years little corn silage has been fed to horses and mules, but it is now being fed with success on a large number of farms. It is preferable not to feed it as the sole roughage, rather using it as a partial substitute for hay. Nourse of the Virginia Station[76] fed 6 mules and 2 horses during winter on hay, corn, and from 50 to 200 lbs. of corn silage per head weekly. The conclusion was that corn silage is a good roughage for horses when combined with hay, corn stover, and grain. Nourse holds that most of the troubles caused by feeding silage to horses come from not gradually accustoming the animals to this feed, from feeding too heavily, and from not realizing that silage often contains much corn. In trials at the North Carolina Station[77] Burkett found that 2 lbs. of silage replaced 1 lb. of clover or oat hay when fed in properly balanced rations to horses or mules. As shown in the following chapter (**533**), corn silage may be satisfactorily employed in fleshing horses for market. Trowbridge of the Missouri Station[78] states that according to successful horsemen, good legume hay and corn silage is a satisfactory ration for wintering mature in-foal mares. He points out that horses at hard work cannot be expected to consume heavy allowances of silage, on account of its bulky nature. Pearson[79] of the University of Pennsylvania, investigating an outbreak where 5 horses suddenly died, found that moldy silage had been fed. On feeding half a bushel of the moldy silage paralysis of the throat occurred, followed by death. When water which had percolated thru this moldy silage was given to a horse it likewise proved fatal. Wing[80] reports the death of 8 horses from eating waste silage thrown into yards from racks where lambs were being fed. In view of such remotely possible troubles, silage should be fed to horses only where intelligent supervision insures the use of good material given in moderation to animals gradually accustomed thereto. (**411**)

511. Roots; tubers; fruits.—The only importance of roots for horse feeding in most sections of this country is as an aid to digestion, for the cereals generally furnish nutriment at lower cost. (**365**) Carrots, especially relished by horses, are great favorites with horsemen when cost of keep is not considered. They are most helpful when it is necessary to carry horses along in high condition, as in stallion importing establishments. (**372**) Parsnips rank next in value. (**373**) In his extensive studies of roots for the horse Boussingault found[81] that it required 400 lbs. of rutabagas (swedes) or somewhat over 350 lbs. of carrots to replace 100 lbs. of good meadow hay. (**370**)

Boussingault found that artichokes were eaten greedily and with good results by horses, about 275 lbs. of the tubers replacing 100 lbs. of hay.

[76] Va. Bul. 80.
[77] N. C. Bul. 189.
[78] Mo. Cir. 72.
[79] Expt. Sta. Rec., 12, p. 886.
[80] Breeder's Gaz., 45, 1904, p. 568.
[81] Rural Economy, p. 400.

(**375**) Potatoes, according to Pott,[82] may be fed raw or cooked in amounts as high as 17.5 lbs. per day along with suitable dry feed. Larger quantities sometimes cause digestive disturbances. Boussingault states that 280 lbs. of cooked potatoes mixed with cut straw replaced 100 lbs of hay. (**374**)

As horses are usually fond of fresh fruit it may sometimes be profitably fed in moderate allowance when there is no market for it. Dried fruits, slightly injured and thereby unsalable, have been successfully fed to horses. (**384**)

512. Wet beet pulp.—Wet beet pulp is unsuited for work horses, according to Pott,[83] altho it may be fed to idle horses at the rate of 22 to 44 lbs. per head daily. Larger quantities are said to be injurious. Clark[84] of the Utah Station reports that colts were allowed constant access to pulp at a sugar beet factory for several years without trouble arising. He fed as much as 20 lbs. of fermented pulp daily to work horses without injury, altho in later trials horses took to the pulp reluctantly and their appetite gradually decreased.

VI. Cost of Keep

513. Feed consumed yearly.—Only a limited amount of data are available relating to the total annual feed consumption of horses. During 2 years Burkett at the New Hampshire Station[85] recorded all feed eaten, water drank, and hours of work performed by 5 farm horses, averaging 1,230 lbs. They worked on the average 2,146 hours a year, or about 7 hours for each working day—a large aggregate for farm horses. The following table shows the amount and cost of the feed consumed annually per horse:

Feed consumed annually by the horse

	Yearly consumption per horse Lbs.	Cost of feed Dollars
Concentrates		
Oats, 36 cents per bu	1,004	11.30
Corn, $16 per ton	2,557	20.46
Wheat bran, $17 per ton	1,071	9.10
Gluten feed, $18 per ton	153	1.38
Linseed meal, $28 per ton	144	2.02
Cottonseed meal, $26 per ton	23	.29
Total concentrates	4,952	44.55
Roughages		
Timothy hay, $16 per ton	3,654	29.23
Corn stover, $5 per ton	219	.55
Total roughages	3,873	29.78
Total feed	8,825	74.33
Water drank	27,992	

Each horse consumed 4,952 lbs. of concentrates and 3,873 lbs. of roughage per year, or about 13.6 lbs. of concentrates and 10.6 lbs. of roughage per day. The water drank averaged nearly 80 lbs. per head daily. With

[82] Handb. Ernähr. u. Futter., II, 1907, p. 368.
[83] Handb. Ernähr. u. Futter., III, 1909, p. 299.
[84] Utah Bul. 101.
[85] N. H. Bul. 82.

feeds at the prices given, the keep of each horse cost $74.33 per year, or 3.4 cents for each hour of work.

Grisdale of the Ottawa Experimental Farms[86] reports that each of the 19 station horses consumed during a year an average of 6,225 lbs. of meal or grain and 5,500 lbs. of hay. The average cost of feed per horse was $99.80 per year, or 27.3 cents per day. It may therefore be held that a 1200 to 1400-lb. work horse will consume from 2.5 to 3 tons of concentrates—grain, meal, etc.—and from 2 to 3 tons of roughage—hay, straw, etc.—annually.

[86] Ottawa Expt. Farms, Rpt. 1902.

CHAPTER XX

FEEDING AND CARING FOR THE HORSE

With the brief bill of fare usually adopted for the horse the administration of feed would seem a simple matter. It is, however, far from such. Given two grooms with similar conditions as to horses to be cared for, work performed, and feed bins to draw from, widely different results are shown. In one case the team emerges from the stable with an action and style which at once announce it in the best of condition. In the other the lagging step, dull eye, and rough coat tell better than words the lack of judgment in feeding and management. The unsatisfactory condition has not necessarily been brought about by any saving at the feed bin and hay mow. Indeed, the poorer groom usually makes the more frequent requests for supplies. The indescribable qualities which, rightly commingled, mark the good feeder, cannot be acquired from lectures or books, but must, in a large measure, be born in the horseman. Study and observation will add to the ability of the alert feeder, but all that may be written will not make an adept of one who does not take to the work naturally.

No one can study the practices of successful horsemen without being strongly impressed with the fact that there are several ways of reaching the desired end of high finish and fine action with the horse. The skill of the "artist" horse feeder enters, along with the food he supplies, into the very life of the creature he manages. If the reader finds the counsel here given on feed and management not entirely to his satisfaction, let him remember that we have chosen a rational and generally applicable course, conceding that good results may also be obtained by following other systems.

I. The Brood Mare, Foal, and Growing Horse

514. Feed and care of brood mare.—It has been estimated that only 60 per ct. of the mares that are bred each year produce living colts.[1] Yet the greater part of this enormous loss can be prevented by proper feed, care, and management of the brood mare. Idleness, the bane of horse breeding, should be avoided. (**111**) Working mares are more certain of bringing good foals than idle ones, but judgment must always be used in working them. Pulling too hard, backing heavy loads, wading thru deep mud, or other over-exertion must be avoided. When not working, the mare should be turned out daily for exercise. As foaling time ap-

[1] McCampbell, Kan. Bul. 186.

proaches, the work should be lightened, and preferably discontinued 3 days to a week before foaling, altho in many instances mares have been worked up to the day of foaling without harm.[2] When laid off, she should not stand in the stall without exercise. A roomy, well-lighted, well-ventilated box stall with wide doorway and ample bedding is none too good at such times. Mares heavy in foal are apt to be cross and quarrelsome, but they should always be handled gently.

The feeding of the working brood mare is easier than that of the idle one. The essentials are a well-balanced ration of good feeds, containing a liberal supply of protein, lime, and phosphorus. An abundance of these is especially needed by immature pregnant mares and pregnant mares which are suckling foals, since in addition to the demand from the developing fetus there is the draft for the growing body of the mother in the one case, and for milk secretion in the other. (**113, 120, 150**) All feeds should be free from dust, mold, or decay, which might cause abortion. Mares used only for breeding purposes do well without grain when on nutritious pasture. With insufficient pasture and in winter some grain should be given. The feed should not be concentrated in character, but should have considerable bulk or volume. The bowels should be kept active thru a proper combination of such feeds as bran, linseed meal, roots, etc.

515. Gestation period and foaling time.—The average period of gestation for the mare is about 11 months, or 340 days, tho it may vary quite widely. William Russell Allen of Allen Farm,[3] Pittsfield, Massachusetts, from records of 1,071 foals produced by trotting mares during 15 years, found the maximum gestation period 373, the minimum 319, and the average 340 days. A wider range was observed by Tessier,[4] who reports that the shortest gestation period of 582 mares was 287, the longest 419, and the average, 330 days.

Only the quick-maturing draft filly should under any circumstances be bred as a 2-year-old; all others when past 3 years. If the desire is to improve the strain of horses, one should not attempt to breed even the draft filly at 2 years of age, but when market draft horses are wanted it may prove economical and will not injure the filly to any noticeable degree if she is well-grown for her age and is properly fed and cared for.

Shortly before foaling the grain allowance should be decreased and laxative food more freely used, since it is advisable to keep the bowels somewhat loose rather than otherwise. When wax forms on the mare's teats, or dugs, the foal may be expected in 3 to 4 days. To avoid infection which may cause navel and joint disease, the stall should be thoroly disinfected before the foal is born. Alexander[5] advises removing all litter, scraping the floor, and scrubbing it and the walls with a good disinfectant. The ceiling should be cleaned, and freshly made whitewash, to each gallon of which has been added one-third pound of chlorid of lime, applied

[2] Harper, Management and Breeding of Horses, p. 284.
[3] Catalog, 1905. [4] Farmers' Cyc., Johnson, p. 562. [5] Wis. Cir. 13.

to both walls and ceiling. The floor should be covered with fresh, clean straw, as free as possible from chaff and dust, and all manure removed as soon as dropped.

As foaling time approaches, the mare should be watched so as to render assistance, if necessary, yet she must not know that anyone is on guard, for often a mare will not give birth to her foal when persons are present, if she can delay it. The mare should be given a half bucket of water before foaling, and when on her feet again she will need a drink of water or, better, of gruel made from half a pound of fine oatmeal in half a bucket of lukewarm water. A light feed of bran is good for the first meal, and this may be followed by oats, or by equal parts, by bulk, of corn and bran. After foaling the mare should be confined for a few days, her ration being simple and not too abundant. With favorable conditions, after 4 or 5 days she may be turned to pasture, and in about 2 weeks, or even before if work is urgent and the mare has fully recovered, she may go back to light work, for a part of the day at least.

516. Fall foaling.—Altho the natural and customary foaling time is in the spring, where the mare must do a hard season's work or when she does not get in foal from spring service she may be bred to foal in the fall.

517. The foal.—It is of the highest importance in horse rearing that the foal start life in full health and vigor, and to this end it should, immediately after birth, take a good draft of the colostrum, or first milk, of the dam, which possesses regulating properties that tend to relieve the alimentary tract of fecal matter collected therein before birth. (**115**) If this result is not accomplished naturally, a gentle purgative of castor oil or a rectal injection is necessary. On account of the great danger from navel and joint disease the navel cord should receive attention immediately after birth, and the stump be carefully disinfected. To prevent germ infection of the intestinal tract of the foal, which causes scours, it is well to wash the udder of the mare with a lukewarm 2 per ct. solution of coal-tar disinfectant and then rinse it off with warm water before allowing the foal its first meal. The tail and hind parts of the mare should likewise be washed once a day for the first week.

Some dams, more frequently those with their first foal and those too hard-worked, fail to supply the proper amount of nourishment, and the young languish. In such cases the mare should be provided with food which will stimulate the milk flow. Good pasture grass is, of course, the best, but in its absence concentrates should be given in the shape of oats, rolled barley, wheat bran, etc., with an equal weight of corn. Sometimes the foal suffers from an over-supply of nourishment, or because the milk is too rich, and the indigestion resulting may terminate in diarrhea. In such cases the dam's ration should be reduced and some of her milk drawn, remembering always that the last portion carries the most fat, which is usually the disturbing element.

518. Weight and gains of foals.—Allen[6] found from the records for 1,071 trotting-bred foals that the weight of the fillies at birth ranged from

[6] Allen Farm Catalog, 1905.

74 to 144 lbs., averaging 109 lbs., while the males weighed from 66 to 152 lbs., averaging 111 lbs. The average birth weight was 110 lbs. During the first year they gained 534 lbs., or nearly 5 times their birth weight. For the second year the average gain was 264 lbs., the third, 118 lbs., and the fourth, 76 lbs., bringing the total at the end of 4 full years up to 1,102 lbs. These colts made more than half their growth during the first year of their life.

Data on the gains of 35 draft colts, from high-grade or pure-bred mares averaging 1,700 lbs. and sired by stallions averaging nearly 2,000 lbs., have been compiled by the Breeder's Gazette.[7] The birth weights of the foals were not reported, but the weights and gains after the first month were as follows:

Weights and gains of draft foals from birth to two years

Period	Wt. at end Lbs.	Daily gain Lbs.	Period	Wt. at end Lbs.	Daily gain Lbs.
Birth—1 mo.......	345	...	6— 7 months..	890	2.0
1—2 months......	465	4.0	7— 8 months..	960	2.3
2—3 months......	570	3.5	8—10 months..	1,085	2.1
3—4 months......	675	3.5	10—12 months..	1,170	1.4
4—5 months......	760	2.8	12—18 months..	1,445	1.5
5—6 months......	830	2.3	18—24 months..	1,590	0.8

These colts were well fed with the intention of making them as large as their parents. Some were given grain and cow's milk before weaning, while others had only hay and good pasture until after weaning. The figures show that at 12 months a well-fed draft colt weighs more than half as much, and at 24 months about three-fourths as much as at maturity. The daily gains were by far the largest before weaning and gradually decreased as the colts matured. If the foal is to reach full development it must not be stunted during the first year of its life.

519. Feeding the foal.—By placing the feed box low, when 3 or 4 weeks old the foal will begin nibbling from the mother's supply and will soon acquire a taste for grain. The earlier the foals so learn to eat, the more independent they become, and the mare will then be able to do more work. Crushed oats or oatmeal, with bran, are excellent feeds, as is a mixture of 4 parts of crushed corn, 3 of bran, and 1 of linseed meal. Colts should be given good clover, alfalfa, or other legume hay as soon as they will eat it, and all the clean, pure water they want. Watchfulness should always detect the first appearance of ailment. Diarrhea brought on by overfeeding or exposure must be checked by giving parched flour, rice-meal gruel, or boiled milk; and constipation, the other common evil, may be relieved by castor oil and injections of warm water, flaxseed tea, sweet oil, etc., administered preferably with a fountain syringe having a small hard rubber nozzle. Harm may be done by injecting a large quantity of strong soapy warm water with an ordinary "horse" syringe. In all cases of derangement the food for both dam and foal should at once be lessened, since nothing aids nature more at such times than reducing the work of the digestive tract.

[7] Breeder's Gaz., 59, 1911, p. 1223.

When the mare is worked, the colt should be left in a cool, dark stall during the day, where he will be safe and not be bothered by flies, rather than allowed to follow the dam about the field. The mare should be brought to the barn to suckle the colt in the middle of the forenoon and afternoon. The colt should not be allowed to drain the udder when bursting full of hot milk, as indigestion and scours are apt to follow. Allow the mare to cool off, and perhaps draw some of the milk by hand before turning her into the stall with the foal. Brood mares at work and nursing strong foals should be heavily fed to sustain a good milk flow. If the mare is worked during the day it is well to turn both dam and foal onto grass pasture at night, and in addition feed a liberal allowance of grain. (**150**)

When dams and foals are running at pasture, a creep should be constructed whereby the foals can have access to a separate supply of grain. Build a pen in the pasture near where the horses are inclined to loiter, making it so high that the mares will not try to jump it, and with sufficient space from the ground to the bottom rail to allow the foals to pass under. Put in a handy gate or bars, then an ample feed trough. After the mares and foals have eaten together within the pen a few times, the foals will visit the place regularly after their dams are shut out. To induce the dams to loiter about, it is well to keep a large lump of rock salt near by and occasionally give a feed of oats at the pen. If flies torture the foal, it is better to keep the mare and foal in a darkened stall during the day and turn to pasture only at night.

520. Mare's milk.—Mare's milk is white or bluish in color with an aromatic, sweetish, slightly bitter taste. As the following table[8] shows, it is more watery than average cow's milk, and while it contains more sugar, it is decidedly poorer in casein, albumin, and ash. (**115**)

Composition of mare's and cow's milk

	Number of analyses	Water Per ct.	Casein and albumin Per ct.	Fat Per ct.	Sugar Per ct.	Ash Per ct.	Specific gravity
Mare's milk...	72	90.58	2.05	1.14	5.87	0.36	1.0347
Cow's milk....	705	87.27	3.39	3.68	4.94	0.72	1.0313

According to Fleishmann,[9] Tartarian mares sometimes remain in milk for 2 years, producing 440 to 490 lbs. of milk annually beyond the requirements of their foals. Vieth[10] reports that good Russian milking mares, when milked 5 times a day, as is the practice, yield 4 to 5 quarts of milk daily.

The foal may be taught to drink cow's milk by pouring it upon meal. The young thing readily eats the moistened feed, and by tipping the pan it soon learns to drink the milk. At the Iowa Station[11] Wilson and Curtiss

[8] König, Chem. Nahr. u. Genuss-mittel, 1904, II, pp. 602, 663.

[9] Lehrb. Milchwirtschaft, 1901, p. 65.

[10] Landw. Vers. Stat., 31, 1885, p. 354.

[11] Iowa Bul. 18.

successfully fed whole milk, and later separator skim milk to imported Percheron, Shire, and French-Coach weanling fillies shortly after their arrival from abroad and while out of condition. In changing from whole to separator skim milk the amount was reduced for a day or two to prevent scouring. Ten lbs. of separator skim milk was found equal to 1 lb. of grain. Grattan[12] reports favorably on the use of skim milk for foals, even when the milk is sour or lobbered. MacNeilage[13] objects to the use of cow's milk for foals, claiming "no better means of manufacturing wind-suckers was ever devised, and it is rare that yearlings so brought out count for much as 2-year-olds and 3-year-olds"—a timely warning against the too free use of this food.

521. Raising the orphan.—If the mare dies or has no milk the foal may, with proper care, be raised on cow's milk. (**265–6**) Choose the milk from a fresh cow, if possible, and preferably from one giving milk low in fat. To a tablespoonful of sugar add warm water to dissolve, then 3 to 5 tablespoonfuls of lime water, which tends to correct digestive troubles, and enough fresh milk to make a pint. Feed about one-fourth pint every hour for the first few days, always warming to blood heat. A satisfactory method of feeding the foal is to use an ordinary nursing bottle with a large nipple, tho, as Johnstone[14] suggests, an old teapot may be used, over the spout of which the thumb of an old kid glove, pierced with holes by a darning needle, has been tied. Whatever utensil is used, it should be thoroly cleansed and scalded before each meal. Such feeding means much bother, but many foals have been killed by neglect of these important details. As the foal grows, the amount of milk may be gradually increased, the period between feedings lengthened, and whole milk substituted. After a few days 6 feedings a day will suffice and later only 4. At 3 to 4 weeks of age the use of sugar may be stopped but it is well to continue the lime water. In 5 or 6 weeks sweet skim milk may be gradually substituted for whole milk, and after 3 months the colt may be given all it will drink 3 times a day. If allowed to suck the attendant's fingers the foal will soon learn to drink from a pail. The bowels should move freely, but if scours occur at any time Alexander[15] advises giving 2 to 4 tablespoonfuls of a mixture of sweet oil and pure castor oil shaken up in milk, and stopping the feeding of milk for 2 or 3 meals, allowing instead only sweetened warm water with lime water added. At the earliest possible age the foal should be fed solid food, such as oat meal, crushed oats, corn, bran, and a little oil meal and legume hay. For exercise let the orphan run in a lot or grass paddock.

522. Weaning.—At from 4 to 6 months of age, depending on conditions, the foal should be weaned. When the mare is bred soon after foaling, or if for any reason the dam and foal are not doing well, it is best to wean comparatively early. On the other hand, if the mother has a good milk flow, and her services are not needed, the foal may well be allowed to

[12] Breeder's Gaz., 6, 1884, p. 796.
[13] Trans. Highl. and Agrl. Soc., 1890, p. 152.
[14] The Horse Book.
[15] Wis. Cir. 13.

suckle 6 months. If the foal has been fed increasing quantities of grain as it developed, the weaning process will not be difficult, for the quantity of milk consumed will have been gradually decreased. Complete separation will then cause little, if any, setback to either dam or foal. In parting the dam and foal, keep them well separated, else all must be done over again. Weanlings should be placed in quarters where they can not injure themselves while fretting for their mothers. At such time the grain ration of the mare should be reduced till she is dried off. When the udder becomes so full as to cause uneasiness, part, but not all, of the milk should be drawn.

The education of the colt should not be postponed until it is sought to "break" him as a 3-year-old, and then attempt to bring the independent animal under man's guidance all at once. The young foal should be taught to lead at the halter, stand tied in the stall, and display proper stable manners.

523. After weaning.—We have seen that the foal makes more than half its entire growth during the first year, and that if stunted during this time it will never fully recover. (**518**) Good bone and muscle are of prime importance with the horse, and feeds which tend to produce these should be chosen. (**118-20**) Nothing is superior to bluegrass or other good pasture and oats. Among the concentrates, wheat bran, cottonseed meal, linseed meal, buckwheat middlings, wheat middlings, soybeans, cowpeas, and Canada field peas are rich in nitrogenous matter, which goes to build muscle, and in phosphorus, a prime requisite of the skeleton. All the legume hays—alfalfa, clover, cowpea, etc.—are rich in lime, the principal mineral component of the bones. A combination of such concentrates and roughages as these should furnish abundant bone- and muscle-building material. When properly balanced by nitrogenous feeds, corn, barley, kafir, milo, or emmer may be used as part of the ration. When fed large amounts of alfalfa hay, colts will relish a little timothy or prairie hay, straw, or corn fodder occasionally. If maximum growth is desired it will be necessary to feed some grain even on good pasture. The young horse which is not developing the proper skeleton may be fed substances especially rich in phosphorus and lime, such as 2 or 3 ounces daily of tankage containing ground bone, or 1 ounce daily of ground bone, ground rock phosphate (floats), or precipitated calcium phosphate. These recommendations are based on the results obtained with other farm animals. Unfortunately there are no definite experiments with horses to guide us at this time.

In the case of high-grade and pure-bred draft foals it is especially necessary that the supply of feed be liberal, for the price of the draft horse depends largely on the size attained. Cochel and Severson[16] fed a lot of 10 draft colts during 2 winters and the intervening summer as shown in the following table. The grain fed during most of the trial was a mixture of 5 or 6 parts of shelled corn, 3 of oats, 2 of bran, and 1 of lin-

[16] Penn. Bul. 122.

seed meal. On account of limited pasture an unusually large allowance of grain was necessary during the summer.

Feed eaten and gains made by draft foals

Average ration	Total gain Lbs.	Daily gain Lbs.
First winter, 168 days		
Grain mixture, 5.8 lbs.		
Hay 10.6-13.1 lbs.; or corn silage 8.2 lbs. and hay 7.4 lbs.	244	1.45
Summer, 196 days		
Grain, 6.7 lbs.		
Hay, 6.0 lbs.		
Pasture	264	1.34
Second winter, 168 days		
Grain, 9.2 lbs.		
Hay, 17.1 lbs	219	1.30

In this trial no effort was made to secure extreme weight, the colts being merely kept in good growing condition. It will be noted that the gains gradually decreased as the colts approached maturity. The average cost of feed was $53.97 per head for the first year after weaning, or $92.96 during the entire 18 months.

524. Substitutes for oats.—To determine the value of a mixture of 14 parts corn, 5 of bran, and 1 of linseed meal as a substitute for oats, McCampbell[17] of the Kansas Station fed 2 lots of high-grade draft colts as shown below for an entire year, beginning in January of their first year. The cost figure includes feed, labor, and veterinary service for a year.

Substitutes for oats in feeding colts

Feed per colt during year	Total gain Lbs.	Daily gain Lbs.	Cost per colt Dollars
Lot I, 8 colts			
Oats, 2,820 lbs.			
Alfalfa hay, 2,625 lbs.			
Corn stover, 528 lbs.			
Straw, 183 lbs.			
Pasture during summer	459	1.27	68.78
Lot II, 10 colts			
Grain mixture, 2,828 lbs.			
Alfalfa hay, 2,625 lbs.			
Corn stover, 528 lbs.			
Straw, 183 lbs.			
Pasture during summer	496	1.38	62.22

The colts in Lot II made larger gains and at a lower cost, showing that the grain mixture used was entirely satisfactory as a substitute for oats, as well as less expensive. (**474**) During the summer it was necessary to feed more grain than usual on account of scant pasture.

That colts may make fair gains when fed no grain after the first winter is shown in a trial by Synder[18] of the North Platte Station, Nebraska, in which 3 lots of foals were fed for 3 years after weaning. The colts were fed as shown in the table, all receiving grain during the first winter only, when 4 lbs. per head daily was fed.

[17] Information to the authors.

[18] Nebr. Bul. 130.

Rearing colts with but little grain

	Average gain Lbs.	Final wt. Lbs.
Alfalfa hay in winter, alfalfa pasture in summer	678	1,268
Alfalfa hay in winter, native pasture in summer	611	1,228
Prairie and sorghum hay in winter, native pasture in summer	540	1,158

The colts fed alfalfa hay in winter and grazed on alfalfa pasture in summer made the largest gains. Snyder concludes that with plenty of native pasture available, it did not pay under his conditions to pasture the alfalfa in summer. However, it paid to feed alfalfa hay in winter rather than prairie and sorghum hay. (**506**)

525. Forcing draft foals.—During 2 winters Fuller[19] fed a total of 11 pure-bred draft foals at the Wisconsin Station for periods ranging from 140 to 223 days all they would eat of a mixture of ground oats 60, corn meal 15, bran 10, and cut alfalfa hay 15 per ct. At the beginning of the first trial uncut alfalfa hay was offered in addition, but very little was consumed. The foals ate on the average 16.5 lbs. a day of this mixture and made gains averaging 2.1 lbs. per day. On this ration they weighed from 1000 to 1200 lbs. at the age of a year, with an estimated cost of $51.66 for feed for the entire year. Such heavy feeding of grain as this will usually prove profitable only in the case of high-grade or pure-bred foals.

526. Cost of raising horses.—The average total cost of raising colts on farms to the age of 3 years, according to estimates received from over 10,000 farmers in various sections of the United States by the Bureau of Statistics, United States Department of Agriculture,[20] is $104.06. If we deduct the value of the work done by the average colt before his third year, the net cost is $96.54, or 70.9 per ct. of the estimated selling price, $136.17. The cost in different states varied from $69.50 for New Mexico and $71.59 for Wyoming, to $149.98 for Connecticut and $156.60 for Rhode Island. The average cost is distributed as follows:

Cost of raising colts to 3 years of age

	First year Dollars	Second year Dollars	Third year Dollars	Total cost Dollars
Service fee	12.95	....	....	12.95
Time lost by brood mare	10.06	....	....	10.06
Breaking to halter	2.22	....	....	2.22
Care and shelter	4.98	5.36	6.35	16.69
Cost of grain fed	4.98	7.14	9.56	21.68
Cost of hay fed	4.14	6.61	8.48	19.23
Cost of pasture	2.56	5.41	6.21	14.18
Veterinary and miscellaneous	....	....	....	7.05
				$104.06

It is shown that about 54 per ct. of the total cost of raising the 3-year-old was for feed and 16 per ct. for care and shelter.

[19] Wis. Bul. 240.

[20] Gay, Productive Horse Husbandry.

II. The Stallion

527. Importance of exercise.—In the care of the stallion nothing so vital to his well being is more generally neglected than proper exercise. (**111**) Often his time is spent in idleness, in a poorly-ventilated box stall, away from his kind. Under such conditions it is no wonder that he may contract vices, become unruly or even vicious, and get only a small per cent of colts. The best exercise is honest work, and there is no better advertisement of a stallion than letting him be seen at work on the farm or road. Even during the breeding season a half day's work each day is beneficial. Manifestly, judgment must be used in accustoming "soft" stallions to continued hard work. When real work is impossible he should be exercised on the road each day. The draft horse under ordinary circumstances should travel at least 5 miles a day, while the light horse may jog and trot 6 miles or more.

528. Feeding the stallion.—The ration of the stallion should consist of first class, wholesome feeds, supplying ample protein and mineral matter for thrift and vigor. The choice of feeding stuffs will depend on the particular locality, the same principles applying as in the case of the work horse. A few combinations given by McCampbell[21] as satisfactory in practice may prove suggestive.

1. Oats; timothy or prairie hay.
2. Oats, 4; corn, 6; and bran, 3 parts by weight; timothy or prairie hay.
3. Oats, 4; corn, 6; linseed meal, 1 part; timothy or prairie hay.
4. Corn, 7; bran, 3; linseed meal, 1 part; timothy or prairie hay.
5. Corn; alfalfa hay 1/3 and prairie hay 2/3.

No specific directions can be given as to the total amount of feed required, since this depends on the exercise the animal gets and whether he is a "hard" or "easy" keeper. A safe rule is to keep the stallion in good flesh, but not "hog fat," for this will injure his breeding powers. Most horsemen advise that in the breeding season he be kept gaining just a bit, rather than allowed to run down in flesh. While some recommend feeding 3 times a day, 4 is preferred by others. In either case no more should be fed than will be promptly cleaned up.

529. General hints.—On the care of the stallion Sanders[22] writes, "Anything that adds to the health, strength, and vigor of the horse will increase his virility or sexual power, simply because the sexual organs will partake of the general tone of the system; and on the contrary, whatever tends to impair the health and vigor of the general system will have a deleterious effect upon the sexual organs." The stall should be kept clean, well lighted, and well ventilated. As a horse likes companionship, it is well to have the stallion's stall near those of other horses. He should be regularly and thoroly groomed and frequent attention should be given his feet. The idea that drugs, nostrums, or stock foods are necessary to

[21] Kan. Bul. 186.

[22] Horse Breeding, pp. 144-146.

increase the ability of the horse to get foals is sheer nonsense. The most successful grooms utilize only good food, carefully and regularly administered.

It is important to conserve the energies of the stallion by regulation of the services, as many horses are otherwise injured. No definite rule can, however, be given, as the number of mares that can be bred will depend on many factors.

III. Work Horse and Mule; Fattening and Fitting Draft Horses

530. The work horse.—Under favorable conditions the regularity in work, feeding, and rest brings comfort and long years of usefulness to the work horse. The general principles which govern the production of work by the horse, the factors influencing his efficiency as a machine for work, and the various feeds employed for his maintenance have been discussed in detail in the preceding chapters. The ration to be fed will depend upon the size of the animal and the nature and severity of the work, as has been shown before. (**450–6**) As a rule from 10 to 18 lbs. of concentrates should be fed daily, the total allowance of grain and hay ranging from 2 to 3 lbs. per 100 lbs. of horse. The ratio of concentrates to roughage will be governed by the severity of the work. (**457**) The morning meal should be light, not over one-third the daily allowance of concentrates, with a small allowance of hay. The mid-day meal is sometimes omitted, especially with horses on the street all day, tho most horsemen believe that some grain should be fed then. The heaviest allowance of concentrates and most of the roughage should be fed at night. (**492**) On idle days the concentrate allowance should always be decreased. There is no more common error in the management of horses than on this point. Girard[23] found that when hard-worked horses getting 19 quarts of oats with 14 lbs. of hay and straw without limit were stopped from work for 3 days and fed the same ration, paralysis, resulting in death, would often occur. By reducing the ration during idle days to 6 quarts of oats at noon and 6 quarts of bran mash both night and morning, with roughage as before, the trouble ceased.

On coming to the stable at noon, the work horse should have a drink of fresh, cool water, care being taken, if he is warm, that he does not drink too rapidly or too much. Before going to work he should be watered again. (**463–4**) The harness should be removed so he can eat his meal in comfort and rest easily. If possible, an hour should be given for the mid-day meal. When the horse comes in after the day's labor, after giving him a drink, unharness at once, and when the sweat has dried brush him well. (**468–70**)

Many rations successfully fed to work horses have been given and discussed in Chapter XIX, but it will also be suggestive to study the following rations which have been employed with good results in different parts of the country.

[23]Langworthy, U. S. Dept. Agr., Office of Expt. Sta., Bul. 125.

Rations for various classes of work horses *

Omnibus horses

Paris, France, wt. 1240 lbs.
Corn, 10.8 lbs.
Oats, 8.1 lbs.
Hay, 8.7 lbs.
Straw, 8.2 lbs.

Fire company horses

Boston, Mass., wt. 1400 lbs.
Ground grain, 9.4 lbs.
Hay, 18.0 lbs.

Chicago, Ill., wt. 1350 lbs.
Oats, 4.0 lbs.
Hay, 15.0 lbs.

St. Louis, Mo., wt. 1350 lbs.
Oats, 10.0 lbs.
Bran, 2.5 lbs.
Hay, 7.0 lbs.

New York, N. Y., wt. 1350 lbs.
Oats, 12.0 lbs.
Hay, 9.0 lbs.

Express horses

Richmond, Va., summer, wt. 1400 lbs.
Corn, 4.7 lbs.
Oats, 5.3 lbs.
Bran, 0.8 lb.
Corn meal, 4.2 lbs.
Hay, 15.0 lbs.

Richmond, Va., winter, wt. 1400 lbs.
Corn, 4.4 lbs.
Oats, 7.5 lbs.
Bran, 0.8 lb.
Corn meal, 0.2 lb.
Hay, 16.0 lbs.

Jersey City, N. J., wt. 1325 lbs.
Corn, 2.0 lbs.
Oats, 19.0 lbs.
Bran, 1.5 lbs.
Hay, 9.5 lbs.

Boston, Mass., wt. 1325 lbs.
Corn, 12.0 lbs.
Oats, 5.3 lbs.
Hay, 20.0 lbs.

Cab horses

New York, N. Y., wt. 1200 lbs.
Oats, 14.0 lbs.
Hay, 10.0 lbs.

Washington, D. C., wt. 1200 lbs.
Oats, 10.0 lbs.
Corn, 5.0 lbs.
Hay, 23.0 lbs.

Cab horses, cont.

San Francisco, Cal., wt. 1350 lbs.
Oats, 8.0 lbs.
Hay, 16.0 lbs.

Horses at severe work

Chicago, Ill., daily, wt. 1500 lbs.
Oats, 7.5 lbs.
Hay, 20.0 lbs.

Chicago, Ill., holiday, wt. 1500 lbs.
Oats, 2.0 lbs.
Bran, 2.5 lbs.
Oil meal, 0.2 lb.
Hay, 20.0 lbs.

South Omaha, Nebr., wt. 1500 lbs.
Oats, 15.0 lbs.
Hay, 12.0 lbs.

New York, N. Y., wt. 1600 lbs.
Oats, 23.0 lbs.
Hay, 12.0 lbs.

Washington, D. C., summer, wt. 1600 lbs.
Oats, 19.0 lbs.
Hay, 13.0 lbs.

Washington, D. C., winter, wt. 1600 lbs.
Oats, 12.5 lbs.
Corn, 6.8 lbs.
Mixture—bran 2, corn meal 1.6, cut hay 4 parts—4 lbs.
Hay, 10.0 lbs.

Farm horses, Stations

New Hampshire, wt. 1235 lbs.
Bran, 2.0 lbs.
Corn, 6.0 lbs.
Gluten meal, 6.0 lbs.
Hay, 10.0 lbs.

Massachusetts, wt. 1100 lbs.
Oats, 3.3 lbs.
Crushed corn, 2.7 lbs.
Provender, 6.0 lbs.
Wheat bran, 2.0 lbs.
Hay, 18.0 lbs.

New Jersey, wt. 1150 lbs.
Corn meal, 6.3 lbs.
Dried brewers' grains, 6.2 lbs.
Hay, 8.0 lbs.

Utah, wt. 1120 lbs.
Bran and shorts (1:1), 12.6 lbs.
Alfalfa hay, 16.0 lbs.

Utah, wt. 1230 lbs.
Oats, 12.0 lbs.
Timothy hay, 13.0 lbs.

*Collected by Langworthy and preserved in "A Digest of Recent Experiments on Horse Feeding," U. S. Dept. Agr., 1903, Office Expt. Sta., Bul. 125.

531. Wintering the farm horse.—It has already been shown that the farm horse when idle during the winter may be economically wintered wholly, or in part, on roughages. (**448**) Rather than keep the idle horse too closely confined at such times it is preferable to turn him out daily into a lot, protected from the wind. (**466**) At shedding time, feed some grain even if the horses are idle. Light grain feeding, together with light work, should begin a few weeks before the spring work starts, for horses are soft after a winter of idleness.

532. The mule.—It is often stated that mules require less feed than horses to do a given amount of work. Riley[24] concludes, from long experience with thousands of army mules, that there is no foundation for this statement. At 3 years of age, when shedding his milk teeth, the mule is especially susceptible to digestive disorders. However, he is an excellent feeder, as a rule being more sensible in eating and less likely to gorge himself with feed than the horse, and hence less subject to colic or founder. Indeed, mules are often fed at troughs, like cattle, and allowed to eat all they desire. The mule is not fastidious in his taste and consumes roughages which the horse will refuse. He also endures hot weather better, and because of the peculiar shape of the foot and its thick, strong wall and sole is less subject than the horse to foot lameness. However, the lack of weight and the small size of his foot somewhat unfit the mule for heavy draft in the city, as he does not get a good hold on the pavements.

Tho the mule will endure more neglect than the horse, good care and feed will prove profitable. For feeding the mule the same feeds are available as in the case of the horse, and the same principles apply in suiting the feed to the size of the animal and the severity of the work performed.

533. Feeds for fattening horses.—As the markets demand draft horses in high flesh, in certain districts their fattening has become an important industry. The horses are usually purchased in the fall after farm work is over and gradually accustomed to a heavy grain ration, getting all they will clean up when on full feed. At this time some of the heaviest feeders will consume nearly twice as much as when at hard work, or about 2 lbs. of grain for every 100 lbs. live weight. The feeds utilized are usually corn, oats, and clover or alfalfa hay.

With 3 expert horse dealers for counsel, Obrecht[25] fattened 13 eastern "chunks" at the Illinois Station to determine the relative value of corn and oats and of clover and timothy hay, obtaining the results shown in the following table, in the test which lasted 84 days. Lot I was fed a mixture of corn, wheat bran, and oats and Lot II a mixture of corn, oats, bran, and oil meal, both being fed clover hay. Lot III was fed the same concentrate mixture as Lot II, but with timothy hay.

[24] Farmer's Cyclopedia of Live Stock, 1908, p. 346.

[25] Ill. Bul. 141.

Rations for fleshing horses for market

Average ration	Daily gain	Total gain	Feed for 100 lbs. gain		Cost of 1 lb. gain *	Value of 1 lb. gain *
			Concentrates	Hay		
	Lbs.	Lbs.	Lbs.	Lbs.	Cents	Cents
Lot I, 5 horses Corn, 17.7 lbs. Wheat bran, 2.4 lbs. Oil meal, 0.4 lb. Clover hay, 13.9 lbs.	2.3	192	894	607	13.9	26.6
Lot II, 4 horses Corn, 8.6 lbs. Oats, 8.6 lbs. Wheat bran, 2.4 lbs. Oil meal, 0.4 lb. Clover hay, 13.7 lbs.	3.0	250	674	461	12.4	19.5
Lot III, 4 horses Corn, 8.4 lbs. Oats, 8.3 lbs. Wheat bran, 2.6 lbs. Oil meal, 0.4 lb. Timothy hay, 14.7 lbs.	1.9	158	1,046	781	20.0	22.2

* Corn $0.65 and oats $0.55 per bu.; bran $26.00, oil meal $32.00, clover hay $11.00, and timothy hay $12.00 per ton.

Clover hay proved much superior to timothy hay, the horses in Lot II, fed clover, making 58 per ct. larger gains than those in Lot III, fed timothy, and at a lower cost. Even when fed with clover hay and wheat bran and oil meal, oats and corn produced larger gains than corn alone. In a second trial 3 parts corn and 1 part oats proved more economical than half corn and half oats, when fed with clover hay. When much bran was fed with clover hay the combination proved too laxative. It will be noted that these fattening horses required about the same amount of feed as fattening cattle for a given gain in weight. (Chapter XXVII.)

The value of corn silage and of cottonseed meal for fattening horses is shown in the following trial by Cochel[26] at the Pennsylvania Station in which 1455-lb. light draft horses, or chunks, were fed for 84 days.

Corn silage and cottonseed meal for fattening horses

Average ration	Daily gain Lbs.	Cost of 100 lbs. gain* Dollars
Lot I Cottonseed meal, 1.4 lbs. Shelled corn, 12.3 lbs. Corn silage, 16.9 lbs. Mixed hay, 10.5 lbs.	1.59	13.40
Lot II Cottonseed meal, 1.5 lbs. Shelled corn, 13.1 lbs. Mixed hay, 18.1 lbs.	1.78	13.90
Lot III Oats, 8.0 lbs. Shelled corn, 9.2 lbs. Mixed hay, 17.7 lbs.	1.64	17.80

*Corn $0.50 and oats $0.35 per bu.; cottonseed meal $32, mixed hay $12, and corn silage $2.50 per ton.

[26] Penn. Bul. 117.

Lot I, getting silage, consumed slightly less grain, and made somewhat cheaper tho slightly smaller daily gains than Lot II. The silage-fed horses were sleeker and better finished than those in either of the other lots. Cottonseed meal and corn produced larger and more economical gains, and better finish than oats and corn. For a few days it was necessary to substitute linseed meal for the cottonseed meal with some of the horses which at first refused the latter.

Gramlich[27] reports that many Nebraska feeders have obtained exceedingly satisfactory results in feeding alfalfa hay to horses that were being fattened.

534. Hints on fleshing horses.—Formerly fattening horses were usually confined to stalls and not exercised, as larger gains are then made. Obrecht found that horses getting no exercise gained 24 per ct. more than those walking 2.8 miles daily. Those in single stalls gained 8 per ct. more than others in box stalls, which had more opportunity to move about. If exercise is begun a few days before horses are marketed, a slight physic should be given to get the muscles in trim and the grain allowance cut in half to avoid digestive trouble, later again being gradually increased to the former amount. When clover or alfalfa hay is fed, a bran mash twice a week is usually all that is necessary to keep the legs of these idle horses from becoming stocked. In some cases it is advantageous to give a dose of Glauber or Epsom salts twice a week.

During the last few years many feeders are following the more natural plan of allowing the fattening horses to exercise at will in paddocks.

Altho some feed the horses 5 or 6 times a day, others secure just as good results with 3 feeds. Water should be supplied freely at least twice a day. Usually no feed is administered between 5 or 6 o'clock at night and 6 the next morning. Grooming and blanketing aid in producing a soft, shining coat which increases the selling price. (**468-9**) It is important to keep mangers and feed boxes clean, and to see that the teeth and feet of the animals are in good condition. (**470–1**) With such feeding and care, surprising gains are sometimes made. Craig and Bretell[28] report that one horse gained 5.5 lbs. per day for 50 days. Gramlich[29] states that one feeder reports a daily gain of 4 lbs. each on 150 head fed for 2 months. While it is recognized that horses must be thus fed to top the market, such rapid and excessive fattening is of little benefit and may even be injurious. When put to hard work the horses quickly lose most of the soft flesh acquired by such forcing.

On fattening horses, Cochel[30] writes: "The cost of gains is not the only factor which determines the profit or loss from the operation. Market values fluctuate quite widely during the time necessary for feeding, hence there may be considerable profit or loss due entirely to this factor. Horses that are kept in idleness are quite apt to become blemished or injured on account of playfulness in the stable. The risk of sickness is greater than with cattle, sheep, and hogs. Many horses are unable to stand a long

[27] Nebr. Exten. Bul. 28, 1914.
[28] Breeder's Gaz., 35, 1899, p. 781.
[29] Nebr. Exten. Bul. 28, 1914.
[30] Penn. Bul. 117.

period of forced feeding because of constitutional weakness. Good judgment in buying and selling is necessary. All other conditions being equal, a close study of the selection of rations and methods of feeding will determine the success or failure of those who finish horses for market.''

535. Fitting for shows.—All show horses should be in good flesh, draft classes especially. The advice above given for fattening horses will apply to fitting draft horses for show, except that they must be exercised daily to keep their muscles in good trim. All show horses should be carefully fed, groomed, and exercised to bring them into proper ''bloom.'' Training also counts for much in the show ring.

IV. Feed and Care of the Light Horse

536. Feeding the carriage and saddle horse.—Style and action are primary requisites with these horses, economy of feeding standing second. Good drivers in this country still assert that the oat-fed horse exhibits mettle as from no other feed. Tho oats easily excel any other single grain or concentrate, there are numerous instances in which a properly combined concentrate mixture has given just as good results, as is shown in the preceding chapter. From 8 to 10 lbs. of oats or their equivalent, divided into 3 feeds, should suffice for concentrates, the evening meal being the largest. In case the horse is at all constipated, a bran mash should be given. The hay is usually fed long, for the carriage horse has ample time for his meals. From 10 to 12 lbs. of hay is a liberal allowance, bringing the total ration within 18 or 22 lbs. The carriage horse must be trim in body, and so cannot consume much bulky food, yet we should not forget that the ration must have volume in order that the digestive functions proceed normally. (**107**) With this class of horses the feeder must also guard against undue feeding of laxative foods, such as clover and alfalfa hay, or bran. Carriage horses are usually overfed and exercised irregularly or too little, and mainly for these reasons their period of satisfactory service is often brief. (**466**) On days when they are not driven, oats should be fed only at noon, with a bran mash morning and evening, no difference being made in the quantity of roughage fed.

537. Feeding the trotter.—The single requisite of speed makes the carrying of every pound of useless body weight, and more especially of feed, a serious matter in the management of the trotting horse. There is also to be considered the effect of the food on the character of the muscles formed from it, and especially on the nerve and mettle of the horse. All horsemen agree in regarding oats as the one grain suitable for animals where speed is sought regardless of cost of food. While this opinion prevails in this country, we should remember that the Arab horse usually subsists upon barley.

For information on feeding the trotter we can draw from no better source than Hiram Woodruff,[31] whose advice is here condensed.

After weaning, trotting bred colts should be fed about 2 lbs. of oats per

[31] The Trotting Horse of America, pp. 90-105.

day with an unlimited allowance of hay. As the colt grows older the amount of oats should be increased to 4 lbs. for the yearling, 6 lbs. for the 2-yr.-old before training, and 8 to 12 lbs. for the colt 2 to 3 years old in training, an unlimited allowance of hay being given all this time.

When going into winter quarters, the feed of the trotter should be reduced fully one-half in order to prevent fattening. A few carrots may be given and a bran mash occasionally, with good clean, sweet hay. Horses whose legs must undergo blistering or firing should have more cooling feed, as mashes and carrots, with less oats, in order to reduce the tendency to feverish, inflammatory symptoms. Care must be taken not to permit the animal to get flabby or washy by too much soft food while undergoing treatment. Horses turned out to the field should be fed oats twice a day, for the exposure to the severity of the weather increases the need of heat-giving food. In the spring when shedding, bran mashes are in order to keep the bowels open, but not flax seed or linseed meal, which have a tendency to relax the system too suddenly and to cause the old hair to come away before the new coat is well started.

With the beginning of the season the feed should be increased to 8 to 10 lbs. of oats daily, in which case the horse wants less hay, but may still have all he will clean up unless he is a glutton. It is necessary to muzzle some horses to prevent their eating the bedding, long before the time for the race. No carrots or corn should now be given, unless it is necessary to induce a light feeder to eat his oats by mixing a handful of corn with them.

During the jogging and after preparation, a bran mash about once a week, depending on the condition of the horse's bowels, will be proper. The trainer must never relax his vigilant observation, or let his judgment sleep. During the fast work, preparatory to the coming trial, the horse will be put upon his largest allowance of strong food. Some will not eat more than 8 or 10 lbs. of oats a day; and it is necessary that such light feeders be not over worked. A good feeder ought to have about 12 to 13 lbs. of oats with a fair amount, say 6 to 8 lbs., of hay. Some will eat 16 lbs. of oats a day. Splan[32] states that the famous trotter Rarus consumed 15 lbs. per day in the hottest part of summer. Woodruff, however, holds that any amount over 13 lbs. does more harm than good.

538. Army horses.—Oats, hay, and straw are the standard feeds used for army horses by the great nations, since they best fill the following rigid requirements: All provender for such purposes must not only be palatable and safe, but also widely known articles of trade, easily collectible in vast quantities, readily inspected, and generally uniform in quality; moreover, they must not be subject to excessive waste or deterioration during storage and transportation.

In the United States army the daily allowance of grain is 12 lbs. per head for horses weighing 1,050 to 1,125 lbs., and 9 lbs. for mules averaging about 1,025 lbs. Under unusual exposure, 3 lbs. of additional grain

[32] Life with the Trotters.

daily may be issued. The standard allowance of hay for both horses and mules is 14 lbs., with 100 lbs. of straw for bedding per month.

In Great Britain the ration is 12 lbs. of hay and 10 to 12 lbs. of oats. Eight lbs. of straw per day is fed horses when at the garrison. In the French army a smaller allowance of hay, 6.6 to 8.5 lbs., is given with an allowance of oats ranging from 10.4 lbs. for light horses in time of peace to 14.7 lbs. for the heavier horses in war time. The German army uses cut straw generally in the ration, the roughage ranging from 7.8 lbs. straw and 5.6 lbs. hay in the garrison to only 3.9 lbs. straw and 3.3 lbs. hay when in the field. The allowance of oats ranges from 9.5 lbs. on a light ration in the garrison to 12.6 lbs. on a heavy ration in the field.[33]

With the army horse it is often necessary to use substitutes for the regulation concentrates and roughages. General Carter[34] writes that oats, corn, bran, and sometimes barley, especially in the southwestern states, form the concentrate allowance for the horses of the United States army. Palay, or unhulled rice, was the main reliance of the cavalry horses in the Philippine Islands during the early days of the insurrection. Pott[35] mentions that a stock bread, made of coarsely ground oats, peas, barley, and linseed, with a little salt added, was employed by the Russian cavalry during war time. The kind of hay fed will vary according to the district. Carter writes that besides the common cultivated grasses, there have been accepted at various times in the United States army, hay from gramma grass, bunch grass, and other wild western grasses, various reed grasses, wild oats, and "pulled" corn fodder.

[33] Langworthy, U. S. Dept. Agr., Office of Expt. Sta., Bul. 125.

[34] Horses, Saddles, and Bridles, 1902, pp. 357-379.

[35] Handb. Ernähr. u. Futter., I, 1907, p. 329.

CHAPTER XXI

GENERAL PROBLEMS IN DAIRY HUSBANDRY

I. The Dairy Cow as a Producer of Human Food

Tho the use of milk and dairy products for food dates back to antiquity, dairy farming as now practiced is of recent origin. In the early days cows freshened in the spring, yielded their milk on pasture in the summer, and were "roughed" thru the winter on any forage that was available.

Monrad,[1] a most reliable dairy authority, tells us that in the mountain districts of Norway, in the dawn of dairying, cows on small farms were wintered on straw, birch leaves, reindeer moss, and horse dung, cooked and given as a mash mixed with chaff and leaves, while on large farms the mixture was fed uncooked. As late as the close of the last century, herring hauled inland and stored in snow banks were boiled with horse dung and shavings of mountain ash and birch bark for feeding goats, sheep, and young cattle. Along the coast even now herring, fish offal, seaweed, and ocean algæ are fed in springtime if the hay gives out. The butter yield on the summer mountain pastures in the early times was from 24 to 48 lbs. per cow for the season, and the annual yield of milk from a good cow ranged from 1,600 to 1,800 lbs. While the changes from such primitive conditions have been great, the cow has generously responded to every advancement in feed and care.

539. Dairying and maternity.—When a steer is fattening, the process goes on rapidly at first, but after a time it is accomplished only at a high cost for the feed consumed. How different is the dairy cow which uses her food, not for the formation of fatty tissue to be stored within her own body, but in making food for nurturing her young!

The basis of modern dairying is the maternity of the cow, and success in this art depends upon rationally recognizing this great basic fact.

Whoever will study dairying from this standpoint, first prominently brought to public attention by W. D. Hoard of Wisconsin,[2] will come to regard the cow in a new light and grow into a better dairyman.

540. Economy of the dairy cow.—As land, labor, and feed increase in price, the dairy cow will more and more displace the strictly meat producing farm animals, for she produces human food with far greater economy than does the steer, sheep, or pig. That this change is taking place is brought out plainly by the census statistics, which show that from 1900 to 1910 the number of dairy cows in the United States in-

[1] Hoard's Dairyman, April 16, 1909.

[2] Wis. Farmer's Inst. Bul. 1, and elsewhere.

creased about 20 per ct., tho the total number of all cattle actually decreased. The following table, adapted from Lawes and Gilbert,[3] well shows the relative economy of the dairy cow and the steer as producers of human food:

Relative returns by the cow and the fattening ox in one week

	Protein Lbs.	Fat Lbs.	Sugar Lbs.	Mineral matter Lbs.	Total dry matter Lbs.
Weekly returns from cow when yielding:					
20 lbs. milk daily	5.11	4.90	6.44	1.05	17.50
30 lbs. milk daily	7.67	7.35	9.67	1.57	26.25
50 lbs. milk daily	12.78	12.25	16.12	2.61	43.76
Weekly returns from ox when gaining:					
10 lbs. weekly	0.75	6.35	....	0.15	7.25
15 lbs. weekly	1.13	9.53	....	0.22	10.88

The fattening ox, when making the substantial gain of 15 lbs. weekly, produces in that time 1.13 lbs. of protein or nitrogenous substance, mostly in the form of water-free lean meat. In the same time the cow yielding 30 lbs. of milk daily produces 7.67 lbs. of casein and albumin, or nearly 6 times as much nitrogenous substance. While the ox is laying on 9.53 lbs. of fat, the cow puts 7.35 lbs. of fat into her milk. She also secretes 9.67 lbs. of milk sugar, against which there is no equivalent substance produced by the ox. Changing this sugar to its fat equivalent (**70**), the cow is shown to yield somewhat more fat or fat equivalent than the ox. The ox stores 0.22 lb. of ash, or mineral matter, largely in his bones, while the cow puts into her milk 1.57 lbs. of ash, or over 6 times as much, during this time.

A better measure of the relative economy of the cow and other farm animals in converting the products of the fields into human food is the amount of edible solids yielded for each 100 lbs. of digestible nutrients consumed. As has already been pointed out (**133**), the dairy cow returns about 6 times as much edible solids in her milk for each 100 lbs. of digestible nutrients consumed as the steer or sheep yields in its carcass.

541. Cow and steer further compared.—Trowbridge of the Missouri Station analyzed the entire body of a 1250-lb. fat steer fed at that Station. At the same Station a Holstein cow gave in one year 18,405 lbs. of milk. The following table by Eckles[4] shows the total nutrients in the milk yielded by the cow during the year and in the entire body of the steer:

Dairy cow vs. steer as producer of human food

	Dry matter in 18,405 lbs. milk Lbs.	Dry matter in 1,250-lb. steer Lbs.
Protein substance	552	172
Fat	618	333
Sugar	920	None
Mineral matter	128	43
Total	2,218	548

[3] Jour. Roy. Agr. Soc., Eng., 1895. [4] Hoard's Dairyman, Feb. 25, 1910.

The steer's body contained about 56 per ct. water, leaving 548 lbs. of dry matter, which included not only the edible dry lean meat and fat, but also all other parts of the body—horns, hoofs, hair, hide, bones, tendons, and internal organs. In one year the cow produced 2,218 lbs. of dry matter which was wholly digestible and suitable for human food. In that time she produced enough protein to build the bodies of 3 such steers, fat sufficient for nearly 2, and mineral matter enough for 3, besides 920 lbs. of milk sugar, which is as nutritious as the same weight of cane sugar.

Eckles writes: "These figures show the remarkable efficiency of the cow as a producer of human food. It is because of this economical use of food that the dairy cow and not the steer is kept on high-priced land. When land is cheap and feed abundant the meat producing animals predominate, but when the land becomes higher in value and feed expensive, the farmer turns to the dairy cow." **(199)**

542. Disposition of feed.—In extensive trials covering 9 years Haecker of the Minnesota Station[5] found that cows averaging 910 lbs. in weight and yielding about 24 lbs. of milk daily, containing approximately 1 lb. of butter fat, utilized the digestible nutrients in their feed as follows:

Utilization of daily feed by the dairy cow, per 1000 lbs. live weight

	Total digestible nutrients Lbs.	Per ct. of nutrients Lbs.
For maintenance of the body	7.92	46.5
For manufacture of milk	4.15	24.4
In milk produced	4.95	29.1
Total in feed consumed	17.02	100.0

It is shown that a well nourished dairy cow uses about 47 per ct. of the food she consumes to support her body and 24 per ct. in the work of converting food into milk, and that about 29 per ct. finally appears as milk. This shows the cow to be a more efficient machine than either the horse or the steam engine. **(146)**

543. Dairy vs. beef type.—When in full flow of milk a high producing dairy cow is generally spare and shows an angular, wedge-shaped form, a roomy barrel, spacious hindquarters, and a large udder. This conformation is in strong contrast to that of the low-set, blocky, beef animal, with its compact, rectangular form, and broad, smooth back. These two types are the result of careful breeding with opposite objects in view. The beef animal has been developed to store in its carcass the largest possible amount of meat. On the other hand, for generations the dairy cow has been bred for the primary object of producing large yields of milk and butter fat. The great improvement in productive capacity in each breed of dairy cattle has come thru long-continued selection based on performance at the milk pail. As a result, tho a good dairy cow may put on flesh when she is dry, on freshening the impulse to milk pro-

[5] Minn. Bul. 140.

duction is so strong that she uses all the feed she can consume for the manufacture of milk. Even under liberal feeding she shows little or no tendency to fatten, but rather grows spare and lean as the lactation period progresses.

To determine whether cows of dairy type were more economical producers than those of the beef type, Haecker of the Minnesota Station[6] divided the Station herd into 4 groups, the first including cows of the beef type; the second, those showing less tendency to beefiness; the third, spare cows lacking in depth; and the fourth, spare cows with deep bodies and of distinctly dairy type. The returns from cows of the different types are shown in the following table:

Economy of cows of dairy and beef types

Type	No. of animals	Av. live weight	Dry matter consumed			Feed cost of 1 lb. fat
			Daily	Daily per 1,000 lbs. live wt.	Per lb. fat.	
		Lbs.	Lbs.	Lbs.	Lbs.	Cents
Beef type	3	1,240	20.8	16.7	31.3	17.5
Less of beef type	4	945	20.4	21.0	26.4	15.1
Spare but lacking depth of body	3	875	20.0	23.0	25.5	14.6
Dairy type	12	951	21.9	23.6	21.2	12.1

The table shows that as the cows approximated the distinctly dairy type the amount of dry matter consumed and the feed cost per pound of butter fat decreased in a marked manner. In view of the widely differing nature of the functions of milk and flesh production, it is not surprising that both can not be developed to the highest degree in the same animal. With Smith[7] we must conclude that the most perfect beef cows are not economical milkers, and the best dairy cows are not satisfactory beef makers.

544. Good and poor producers.—To determine the relative economy of high and low yielding cows for producing milk and butter fat, Carlyle and Woll, at the Wisconsin Station,[8] studied the food consumed by and the returns from 33 cows, covering 88 lactation periods extending thru the entire winter. The herd was divided into the following classes according to their productive capacity.

Feed eaten and returns by cows of different quality

Character of cows	Wt. of cows	Dry matter eaten daily	Daily production		Dry matter eaten per—		
			Milk	Fat	1,000 lbs. live wt.	100 lbs. milk	1 lb. fat.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
High producers	956	25.3	26.6	1.2	27.0	102	22
Medium producers	1,133	24.7	21.5	0.9	21.4	119	27
Low producers	1,012	21.1	14.6	0.7	21.1	149	32

[6]Minn. Bul. 35. [7]Profitable Stock Feeding, p. 38. [8]Wis. Bul. 102.

The high grade producers ate much more feed for their weight than the others, yet they required only 102 lbs. of dry matter for 100 lbs. of milk, while the low-grade cows, which ate less feed, required 149 lbs., or almost 50 per ct. more feed for 100 lbs. of milk.

545. Profitable vs. unprofitable cows.—Beach of the Connecticut (Storrs) Station[9] found the cost of feed and the returns from the 5 best and the 5 poorest cows in the Station herd for 5 years to be as shown in the following table:

Comparative returns from profitable and unprofitable cows

	Cost of feed	Yield of fat	Margin over cost of feed	Feed cost of 1 lb. of fat
	Dollars	Pounds	Dollars	Cents
First year				
5 most profitable cows	56.54	304	26.91	18.6
5 least profitable cows	52.02	189	4.09*	27.5
Second year				
5 most profitable cows	60.30	377	43.27	16.0
5 least profitable cows	45.38	164	5.75*	27.7
Third year				
5 most profitable cows	53.24	375	44.25	14.2
5 least profitable cows	43.38	217	15.68	20.0
Fourth year				
5 most profitable cows	59.52	376	43.71	15.8
5 least profitable cows	51.45	237	13.71	21.7
Fifth year				
5 most profitable cows	59.46	366	40.23	16.2
5 least profitable cows	56.11	269	17.67	20.9

* Loss.

The table shows that the good cows ate more feed but gave better returns over cost of keep than the small producers. During the first 2 years the 5 poorest cows did not pay for their feed. By gradual elimination the net loss of about $4 for each of the poorest cows the first year was changed to a gain of $17 per head for the 5 poorest animals in the herd during the fifth year.

Fraser of the Illinois Station[10] reports a cow in the Station herd that in 12 years gave 87,102 lbs. of milk, containing fat sufficient to make 4,318 lbs. of butter. During 3 years a certain cow gave 11,930 lbs. of milk annually, containing 405 lbs. of fat, and returned $42.60 per year over cost of feed. Another with the same feed and care gave in the same time only 3,830 lbs. of milk annually, containing 138 lbs. of fat, and failed by $5.62 per year of paying for her feed.

546. Causes of inefficiency of dairy cows.—Observing a striking difference in the productive capacity of 2 Jersey cows at the Missouri Station, which were raised under the same conditions and were more than half sisters, Eckles and Reed[11] conducted the following trial to find the explanation. During their first 2 lactation periods the better cow had produced 2.8 lbs. of milk and 3.9 lbs. of fat for each pound produced by

[9]Conn. (Storrs) Bul. 29. [10]Ill. Cir. 106. [11]Mo. Res. Bul. 2.

the other. In the third lactation period the cows, calving 3 days apart, were fed the same feeds supplied in the same proportions, the amount fed being so adjusted that neither cow gained or lost in weight. Both were kept farrow and complete records kept and analyses made of the feed consumed and milk produced for the entire lactation period. During the year the better cow consumed 1.75 lbs. of feed for each pound eaten by the other, but produced 2.67 lbs. of milk and 2.77 lbs. fat for each pound yielded by the poorer cow. When dry the better cow required more feed to maintain her weight than the poor one. Her greater efficiency was therefore not due to a lower requirement for maintenance. She digested a slightly larger percentage of her ration, but there was far too little difference to explain her much greater economy in production. There was practically no difference in the amount of milk or fat produced by the cows from each 100 lbs. of feed which they ate in addition to the maintenance requirement. The real cause of the greater efficiency of the better cow was that she was able to consume and utilize a much larger amount of feed above that needed to maintain her body, and hence had more feed available for milk production. The good producer secretes an abundance of milk, on account of her strong inherited impulse to milk production. To replace the nutrients she puts into her product she has a keen appetite and consumes a heavy ration.

547. The basis of profitable dairying.—Good authorities estimate that even in the leading dairy states from one-fourth to one-third of the dairy cows do not pay for their care and feed.[12] The chief reason why such a condition is found now, when the principles of successful selection, feeding, and care of dairy cattle have long been established by scientists and practical dairymen, is that the owners do not know which of their cows fail to yield enough milk to pay for their feed and care. They do not realize that tho the gross income from their herd would be reduced by weeding out the "boarders," their net profits would be materially increased.

Since the basis of profitable dairying is the individual cow, the question arises as to how the dairyman can select the animals to be retained and those, if any, which should be culled out. Competent judges can usually distinguish a cow of very low productive capacity from one of high efficiency by her conformation. However, even experts are often unable to foretell a cow's yield from her appearance alone. The only reliable index to the value of a cow as a profitable producer is the record of the actual amount of milk and fat she has yielded, which record may now be readily secured by the combined use of the Babcock fat test and the milk scales. With records of the production of each cow and the approximate amount of feed she has consumed, the dairyman is in position to eliminate the unprofitable animals and proceed to build up a herd of high producers at little expense by using a bred-for-production sire and retaining all heifer calves from the most profitable cows.

[12] Woll and Harris, Wis. Bul. 226.

II. Milk; Factors Influencing Its Composition and Yield

548. Composition of milk.—As we shall see later (**551–72**), the chemical composition of cow's milk varies considerably, depending especially on the breed, the individuality of the cow, and the length of time she has been giving milk. The average composition of milk in several countries, as presented by Wing,[13] is as follows:

Average composition of cow's milk

	American (Babcock) Per ct.	English (Oliver) Per ct.	German (Fleischmann) Per ct.	French (Cornevin) Per ct.
Water	87.17	87.60	87.75	87.75
Fat	3.69	3.25	3.40	3.30
Casein	3.02	3.40	2.80	3.00
Albumin	0.53	0.45	0.70	....
Sugar	4.88	4.55	4.60	4.80
Ash	0.71	0.75	0.75	0.75
	100.00	100.00	100.00	99.60

It has been pointed out in previous chapters (**115, 150**) that milk is rich in crude protein and ash, especially lime and phosphoric acid, and that hence the ration for the cow should furnish an abundance of these nutrients. Attention has been called to the fact that colostrum, the milk produced by the cow immediately after freshening, differs from ordinary milk in being higher in protein and ash. (**115**)

549. Milk of the various breeds.—The milk of different breeds of cows varies considerably in composition, as is shown in the following table, chiefly from Wing,[14] which summarizes data from various American stations.

Breed	Solids Per ct.	Fat Per ct.
Jersey	14.70	5.35
Guernsey	14.71	5.16
Devon	14.50	4.60
Shorthorn	13.38	4.05
Brown Swiss	13.27	4.24
Ayrshire	12.61	3.66
Holstein-Friesian	11.85	3.42

It is shown that the Jersey and the Guernsey breeds give the richest, and the Ayrshire and the Holstein-Friesian the poorest milk. However, the breeds which give the richest milk usually yield a smaller quantity, so that the total quantity of solids and fat is nearly the same for all dairy breeds.

Eckles and Shaw[15] have shown that the sugar and albumin content of milk varies but little with either breed or individual, while there is a greater range in the percentage of casein. Milks rich in fat are generally high in casein, but the casein content does not increase in the same ratio as the fat content. According to Hart and Tottingham,[16] for each 100 lbs.

[13] Milk and Its Products, p. 17.
[14] Milk and Its Products, p. 33.
[15] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 156
[16] Agricultural Chemistry, p. 291.

of fat in Jersey or Guernsey milk there are as a rule 55 to 65 lbs. of casein, while in Ayrshire and Holstein milk there are 65 to 75 lbs. The ratio of fat to casein shows considerable variation among cows of the same breed. These facts are important in cheese making since the yield of cheese depends not only upon the amount of fat in the milk but also upon its casein content. A milk testing 6 per ct. of fat will not make twice as much cheese as one testing 3 per ct. Hart of the Wisconsin Station,[17] who has invented a simple casein test, advises paying for milk at cheese factories on the basis of the content of both fat and casein.

550. Fat globules.—Collier of the New York (Geneva) Station[18] placed the average secretion of milk by the cows of the station herd at 0.7 lb. or 19.6 cubic inches per hour. He found that the one-thousandth part of a cubic millimeter of average milk contained 152 fat globules, and accordingly that the average station cow secreted 138,210,000 fat globules each second thruout the day of 24 hours while giving milk. Babcock[19] tells us that a quart of average milk contains not less than 2,000,000,000,000 fat globules. These figures are beyond comprehension and should intensify our interest in the marvelous processes of life. They lead us to ponder on the infinite division which food must undergo during digestion before it is useful to animal life.

The fat globules of Jersey and Guernsey milk are considerably larger than those in Holstein and Ayrshire milk, while the size of the globules in Shorthorn milk ranges between. This fact is of practical interest, for cream rises more rapidly in milk containing large fat globules.

551. Influence of individuality.—Individual cows of the same breed differ from one another not only in the amount of milk and fat they produce but also in the composition of their milk, especially the percentage of fat. Indeed the difference in fat content of milk from individuals of the same breed may be as great as the difference between the grand averages for the different breeds. As Eckles[20] points out, the cow that gives the richest milk does not necessarily produce the largest total yield of fat. He holds that as a rule the highest annual productions of butter fat are generally secured with milk carrying the average percentage of fat for the breed or even less.

The composition of the milk from an individual cow often varies considerably from day to day, due to such causes as changes in the health of the animal, change in milkers, excitement, variations in the weather, and to some extent to changes in feed.[21]

To determine the variation in the percentage of fat in single milkings of individual cows, Anderson of the Michigan Station[22] studied 200 seven-day records made under ordinary herd conditions where regular feeding and milking were practiced, and 2000 seven-day records of

[17] Wis. Buls. 156, 197. [18] N. Y. (Geneva) Rpt. 1892. [19] Wis. Bul. 18.
[20] Dairy Cattle and Milk Production, pp. 133–4.
[21] Eckles and Shaw, U. S. D. A., Bur. Anim. Indus., Bul. 157.
[22] Mich. Spec. Bul. 71.

official Advanced Registry tests. From these data he draws the following conclusions: One may expect that during 7 consecutive days about 30 per ct. of a herd of cows will show a range in the percentage of fat in the milk at different milkings of 1 per ct. or less; 50 per ct. of 1.1 to 2.0 per ct.; 14 per ct. of 2.1 to 3.0 per ct.; and the remaining 6 per ct. of the herd even a greater variation. In other words, 6 per ct. of the cows might yield milk testing 3 per ct. of fat at one milking during the week and at some other milking produce milk containing 6 per ct. of fat or over. The fluctuation in the composition of the milk from the same cow is thus much greater than has often been assumed.

552. First and last drawn milk.—At the New York (Geneva) Station[23] Van Slyke analyzed the successive portions of milk drawn from a Guernsey cow with the following results:

Composition of the successive portions of milk as drawn

	Weight of milk Lbs.	Fat Per ct.	Casein Per ct.	Albumin Per ct.
First portion	3.2	0.76	2.67	0.62
Second portion	4.1	2.60	2.57	0.64
Third portion	4.6	5.35	2.49	0.61
Fourth portion	5.8	9.80	2.39	0.58

We learn that the first milk drawn is very poor in fat, each succeeding portion increasing in richness of fat, while the casein and albumin show little change. Those who let the calf have the first milk drawn and reserve the strippings keep the richest milk.

553. Effect of period between milkings.—When the intervals of time between milkings are unequal, other conditions being the same, cows generally yield a smaller amount of milk after the shorter period, but this milk is usually richer in fat. For this reason the evening milk is generally the richest in fat and total solids. With equal intervals between milkings there is no uniform variation in the fat content of the different milkings. When cows are milked 3 times daily at equal intervals, the mid-day milking is usually slightly the richest.[24]

554. Effect of age.—From a study of all the data bearing on the effect of age of the cow on the yield and fat content of milk Eckles[25] concludes:

"A dairy cow on the average as a two-year-old may be expected to produce about 70 per ct.; as a three-year-old around 80 per ct.; and as a four-year-old about 90 per ct. of the milk and butter fat she will produce under the same treatment when mature.

"The richness of milk remains practically constant from year to year, except that after the third milking period there is a slow, gradual decline with advancing years.

"Probably the majority of dairy cattle are rejected from the herd on account of failure to breed, or from udder trouble, before the effect of

[23] Jour. Am. Chem. Soc., 30, p. 1173.

[24] Eckles and Shaw, U. S. D. A., Bur. Anim. Indus., Bul. 157.

[25] Dairy Cattle and Milk Production, p. 153.

advancing years can be observed to any marked extent. It is a fact often observed that a cow may make her best record when 10 or 11 years old, altho as a rule she does her best rather earlier. If a dairy cow continues to breed, she usually shows no marked decline until at least 12 years old. Occasionally a cow continues to breed until she is 16 or 18 years old."

555. Effect of advancing lactation.—Woll of the Wisconsin Station[26] has condensed, in the table following, the findings of the New York (Geneva) Station with 14 cows of 6 breeds, giving the dry matter consumed and the yields of milk and fat, month by month, from freshening until the cows went dry:

Effect of advancing lactation on economy of milk production

Month	Daily yield		Fat	Dry matter eaten daily	Dry matter eaten to produce:		
	Milk	Fat			100 lbs. milk	1 lb. solids	1 lb. fat
	Lbs.	Lbs.	Per ct.	Lbs.	Lbs.	Lbs.	Lbs.
First month	25.1	0.98	4.02	23.6	94	7.1	24.1
Second month	26.0	0.95	3.74	27.0	104	8.2	28.6
Third month	23.8	0.84	3.71	28.9	122	9.5	34.4
Fourth month	21.2	0.79	3.84	29.0	137	10.5	36.8
Fifth month	19.6	0.73	3.87	28.5	146	11.1	39.3
Sixth month	19.8	0.75	3.90	29.3	148	11.2	39.4
Seventh month	19.0	0.72	3.94	28.5	150	11.2	39.7
Eighth month	16.0	0.60	3.89	28.0	175	13.0	46.5
Ninth month	12.5	0.48	3.92	28.0	224	16.1	58.3
Tenth month	9.4	0.41	4.19	26.5	282	19.4	65.3
Eleventh month	5.6	0.26	4.58	24.3	436	28.1	95.5

Immediately after freshening the cows gave richer milk than later. It then grew poorer for a month or two, and after that slowly increased in richness until they became dry. The changes in fat content as the lactation period progresses often seem to follow no definite law, so that generalizations on this point are difficult. The table shows that during the first month after a cow freshens a given quantity of feed gives greater returns in milk product than later, and that the further advanced a cow is in lactation the more food she requires for a given quantity of milk. When fresh the cow usually draws on her own body substance for nutrients used in milk production, and later she is nurturing an unborn calf.

On studying the monthly records of 323 cows entered in the Wisconsin Dairy Cow Competition and tested by the Station of that state, Woll[27] found that the average percentage of fat did not vary over 0.08 per ct. during the first 6 months of lactation. After this the fat content increased gradually up to the ninth month, and more rapidly thereafter.

The combined studies of Carlyle and Woll at the Wisconsin Station,[28] Beach at the Connecticut (Storrs) Station,[29] Linfield at the Utah Station,[30] and the results of the Wisconsin Dairy Cow Competition[31] show

[26] Wis. Bul. 116.
[27] Wis. Res. Bul. 26.
[28] Wis. Bul. 102.
[29] Conn. (Storrs) Bul. 29.
[30] Utah Bul. 68.
[31] Wis. Res. Bul. 26.

that the normal monthly decrease in the yield of milk in well-managed herds is about as follows: From the second to the seventh month the shrinkage varies irregularly, ranging from 4 to 9 per ct. per month, based on the yield of the previous month. The average monthly decrease during this period is about 6 to 7 per ct. After this the decrease becomes more rapid, being 9 to 11 per ct. for the eighth month, 12 to 18 per ct. for the ninth month, and 12 to 23 per ct. for the tenth month, after which the cows are generally dried off.

556. Period of greatest yield.—Haecker of the Nebraska Station[32] studied 239 lactation periods with cows at the Nebraska and Minnesota Stations, the records beginning 4 days after calving. He found that 90 per ct. of the cows made their best records during the first 10 weeks of lactation, and over one-half during the first month. The greatest number gave the most milk during the third week, and the most fat during the second week after calving.

557. Influence of condition at calving.—Observing dairymen have for some time known that cows calving in a fat condition will sometimes yield milk abnormally rich in fat for a short time after calving, losing markedly in weight during this period. This fact has been brought to public attention by Woll[33] and Eckles.[34] At the Missouri Station Eckles fed a mature cow so as to be excessively fat at calving, and thereafter gave her food sufficient only for a dry cow. Beginning with 21 lbs. of milk daily, she was giving 19.5 lbs. at the end of 30 days of such poor feeding, during which time she lost 115 lbs. in weight. Eckles estimates that the 43 lbs. of fat and 53 lbs. of other solids yielded in the milk during this period must have been drawn from her body tissues. During this period her milk averaged 6.1 per ct. fat. Within 48 hours after her feed was later increased it declined about 1.4 per ct.

In another trial Eckles fed one heifer liberally on rich rations from birth until she calved, while another was kept poor and thin. After calving, the milk of the well-fed heifer tested over 4 per ct. fat and that of the thin one about 3 per ct. For several weeks after calving the fat heifer declined in weight, the fat percentage remaining constant. When at length her weight became stationary the percentage of fat declined somewhat. The thin heifer did not lose in weight after calving, and the fat in her milk did not decrease. In the end the milk of the two heifers was about equally rich.

These trials show that when a cow of good dairy temperament calves in high condition, owing to the strong impulse to milk production she will withdraw fat from her body and put it into her milk. While she is doing this the fat content of her milk will be raised abnormally high. This fact is important, for it shows that the total yearly production of fat is increased by having cows in good condition when they calve. The fat they have deposited on their bodies is not wasted, but is returned in the form of the more valuable butter fat. The bearing of this fact on

[32] Nebr. Bul. 76.

[33] Wis. Rpts. 1902, p. 117; 1903, 115.

[34] Hoard's Dairyman, July 9, 1909; Mo. Bul. 100.

the value of short-time tests of dairy cows is obvious, for by having cows calve in a high condition a seven-day record of fat production may be secured shortly after calving which is no index to their ability as long-time producers. Yearly records obviate this criticism.

558. Loss in weight.—Haecker of the Minnesota Station[35] found that cows lose rapidly in weight after freshening. In one case the average decrease for 15 cows was 49 lbs. per cow for the first week, with an average daily loss per cow of 2 lbs. for the first 7 weeks. During this time the cows yielded products in excess of what the food furnished—in some instances twice as much. Such excess of yield gradually decreased until the eleventh week, when cows of pronounced dairy temperament reached equilibrium between the food nutrients consumed and dairy products yielded, while others required a longer time to reach equilibrium.

559. Influence of feed on yield of product.—The quantity of milk and butter fat the cow yields depends directly on the constitution of the animal and her inherent tendency toward milk production. Within these inherited limits, however, it is governed directly by feed, care, and environment. In a state of nature the cow provides only sufficient milk for the nourishment of her young, even tho her feed be abundant. When she is liberally fed, the modern dairy cow, produced thru long-time selection and breeding, secretes far more milk than her calf can utilize. So generous is the dairy cow that few dairymen feed to the limit of profitable production. Within wide limits, then, the quantity of milk a dairy cow yields is directly dependent on the feed and care she receives.

This is shown in a striking manner by a test conducted by Wing and Foord at the Cornell Station.[36] For a full year they recorded the milk and fat yield of a herd of poorly nourished cows kept by a farmer on a New York farm. The herd was then moved to the Station where it was liberally fed for 2 years; then the cows were returned to the farmer who fed them poorly as before. Below appear the average returns of 7 cows so studied:

Effect of continued under-feeding on milk production

	First and fourth years on farm Lbs.	Second and third years at Station Lbs.
Average weekly yield of milk per cow	109	155
Average weekly yield of fat per cow	4.7	7.1

Here is an increase thru good feed and care of 42 per ct. in the quantity of milk and 51 per ct. in the quantity of fat over that obtained by the farmer. When again subjected to the hard conditions enforced upon them by the poor farmer, the cows fell back to their old record.

560. Influence of feed on richness of milk.—Down to the most recent times it was universally held that milk varied in richness, or percentage of fat, from milking to milking, according to the feed and care the cow received daily. We have now come to know that the milk of each cow possesses a fixed, inherent composition, and that normally the richness

[35] Minn. Bul. 79. [36] N. Y. (Cornell) Bul. 222.

of milk is not the immediate sequence of feed and care, provided the cow receives sufficient nutriment to maintain her body weight. Cows starved or greatly underfed may produce milk somewhat lower in fat percentage than normal. However, as is shown in the following paragraphs, under all ordinary conditions the percentage of fat can not be materially altered for any long period of time by the particular kind of feed the cow receives.

The Jersey cow gives milk which is relatively rich in fat, and the Holstein, milk that is relatively low in fat. No kind of feed or care will cause the Jersey to give milk like that of the Holstein, or the reverse. Were a piece of skin, clothed with yellow hair, taken from the body of a Jersey cow and grafted on the body of a Holstein cow, we should expect the grafted portion to continue growing yellow, Jersey-like hair. In the same way, were it possible to graft the udder of a Jersey cow on to the body of a Holstein, we would then expect the Holstein to give Jersey-like milk. It is not the body of the cow or the digestive tract, but the glands of the udder which determine the characteristics of the milk yielded by each individual cow. This is what we should expect, for if milk varied with every slight change of food and condition, the life of the young, dependent on such milk, would always be in jeopardy.

561. Effect of protein-rich rations.—That feeding an excess of protein over the actual amount required for body maintenance and milk production tends to stimulate the cow to a greater yield of milk is shown in trials by Lindsey at the Massachusetts Station.[37] In one test, supplying twice the minimum amount of protein required increased the milk flow 15 per ct. Owing to this stimulation of the yield very narrow rations, i.e., those rich in protein, are commonly employed when cows are being forced to maximum production on official tests. While the yield of milk may be thus increased by feeding an excess of protein, Lindsey concludes from 8 trials that varying amounts of protein do not seem to influence the percentage composition of the milk, making it richer or poorer in fat, for example. On the other hand, the experiments of the Copenhagen Station,[38] covering observations with about 2000 Danish cows and extending over ten years, indicate that the fat percentage was possibly raised as much as 0.1 per ct. thru the feeding of highly nitrogenous rations. Michels of the North Carolina Station[39] found the fat content of the milk slightly higher when a ration having a nutritive ratio of 1:4.0 was fed than when the nutritive ratio was 1:5.7.

562. Effect of feeding fat.—Numerous experiments have been conducted in this country and Europe to determine the effect on the yield and fat content of the milk when various fats are added to the ration. After feeding cottonseed-, palm-, corn-, cocoanut-, and oleo-oil, and stearin, the solid fat from beef, to cows, Woods of the New Hampshire Station[40] concluded that the first effect of such feeding is to increase

[37] Mass. Rpt. 1911, I, pp. 86–121.
[38] Copenhagen Sta. Rpt. 45; Woll, Wis. Bul. 116.
[39] N. C. Rpt. 1911, pp. 90–97.
[40] N. H. Bul. 20.

the percentage of fat in the milk, but with the continuance of such feeding the milk tends to return to its normal composition. Woods holds that the increase in the fat percentage is not due to the oils fed, but to the unnatural character of the food. Lindsey of the Massachusetts Station[41] likewise found that feeding large quantities of oil, either linseed, cottonseed, corn, or soy bean oil, caused a temporary increase in the richness of the milk. That the feeding of fat does not always cause a temporary increase in the richness of the milk is shown in 2 trials by Wing at the New York (Cornell) Station[42] in which tallow was fed to 10 cows while on pasture or on winter feed. Beginning with a small amount, the allowance of tallow was gradually increased until each cow was consuming about 2 lbs. daily, this allowance being continued for several weeks. The tallow feeding had no uniform effect either on the yield of milk or the fat content. During the first 2 or 3 weeks the percentage of fat was increased slightly in the case of some animals, but after this the milk again became normal in composition.

563. Effects of feed on fat composition.—The fat of milk is a composite of many kinds of fat—palmitin, olein, stearin, butyrin, etc. While the kind of feed given the cow does not materially change the percentage of total fat in her milk, in some cases it does seem to alter the relative proportion of the several component fats or otherwise change the character or nature of the fat, as shown by the resultant butter. Many years ago investigators began to study diligently the influence of various feeds on the composition of the fat of milk, and their work is still in progress. The results thus far secured are conflicting in some respects, but in general it has been found[43] that feeds rich in vegetable oils (which contain a large amount of olein) produce milk fat high in olein. This usually tends to make the butter softer, for olein is a liquid fat, but in some instances this tendency is offset by still other changes in the composition of the fat. Cottonseed and cocoanut meal produce firm, hard butter. A change from dry feed to pasture generally produces fat higher in olein and results in softer butter.

564. Withholding lime.—At the Wisconsin Station[44] Hart, McCollum, and Humphrey fed a 1150-lb. cow producing about 30 lbs. of milk daily a liberal ration save that it lacked lime. It was found that there went into the milk daily about 20 grams of lime (CaO) and into the solid excrement and urine, principally the former, about 30 grams, the latter loss being due to the normal changes (metabolism) taking place in the body. In all, about 50 grams, or nearly 2 ounces, of lime disappeared daily from the body of this cow, only one-half of which could have been furnished by the lime in the food. During the trial, which lasted 110 days, this cow maintained a good flow of milk and continued to put the normal amount of lime into it. It was calculated that during the trial

[41] Mass. Rpt. 1908, pp. 109–112. [42] N. Y. (Cornell) Bul. 92.
[43] Lindsey, Mass. Rpt. 1908, pp. 109–112; Hunzicker, Ind. Bul. 159.
[44] Wis. Res. Bul. 5.

she gave off in milk and excrement 5.5 lbs. more lime than she received in her food. It was estimated that her skeleton contained about 24.2 lbs. of lime at the start, and this being true, this cow gave up in 110 days about 25 per ct. of all the lime in her skeleton! Here is a striking illustration of the overpowering force of maternity. **(98, 150)**

565. Turning to pasture.—The Copenhagen (Denmark) Station[45] for 10 successive years studied the changes in milk when cows are turned from winter stables to spring pastures. In all 1,961 fall-calving cows on 8 different farms were used. During the month before turning to pasture the average daily yield was 20.7 lbs. of milk, carrying 3.18 per ct. fat and 8.73 per ct. other solids. For the first month on pasture the average yield was 21.2 lbs. of milk, containing 3.37 per ct. fat and 8.92 per ct. other solids. Turning to pasture increased the milk flow by over 7 per ct., the percentage of fat by about 8 per ct., and the other solids by nearly 2 per ct. While the increased milk flow was maintained, the percentage of fat fell back to normal after the cows had been on grass about 20 days. The small increase in solids not fat seems to have been more permanent.

Humphrey and Woll[46] state that during each of 9 seasons the percentage of fat and the yield was increased on turning the Station herd to pasture. The average increase in percentage of fat was small in all the years, ranging from 0.01 to 0.22 per ct. The increase in average daily yield of fat ranged from 0.02 to 0.16 lb. per head daily. During the first 2 weeks on pasture the herd lost in body weight each season, the average decrease in weight ranging from 1 to 95 lbs.

During 3 of 8 seasons Hills of the Vermont Station[47] found no change in the percentage of fat in the milk on turning to pasture, in 4 seasons an immediate and marked improvement, lasting 2 to 4 weeks, occurred, and in the other, a slight tendency toward increase in fat content.

Linfield of the Utah Station[48] observed that cows turned on pasture early in the season while the grass was soft and lush lost in weight for a short time, due probably to the extreme flushing of the system. This result, however, had no effect on the milk production. Where the grasses were more mature when the cows were first turned on them no material loss in live weight was noted.

566. Temperature and weather.—From 5 tests covering practically the entire year and varying conditions of pasture, summer soiling, and winter barn feeding, Hills of the Vermont Station[49] concludes that the tendency both in summer and in winter is for cows to give richer milk when the temperature falls and poorer milk as it rises. Cows exposed to cold rains shrink in milk flow and may yield milk poor in fat.

567. Effects of drought.—Van Slyke of the New York (Geneva) Station,[50] studying the milk supply of cheese factories during a drought, found that the general effect thereof was to diminish the flow of milk

[45] Copenhagen Rpt. 45; Woll, Wis. Bul. 116.
[46] Wis. Bul. 217. [47] Vt. Rpt. 1907. [48] Utah Bul. 68. [49] Vt. Rpt. 1907.
[50] N. Y. (Geneva) Bul. 68.

rapidly. The fat increased, while the casein, and especially the albumin, diminished. Tho percentagely small, the changes were in the direction of giving the milk the appearance of having been watered—a point of importance with milk inspectors.

568. Exercise, work, and grooming.—Dolgich[51] found that moderate exercise tended to increase the quantity of milk and all the constituents except casein, which was slightly decreased, while excessive exercise decreased nearly all the constituents. Light work decreased the quantity of both milk and milk solids, while excessive work decidedly decreased the flow and injured the quality, the casein not coagulating and some of the food-fat appearing unaltered in the milk. (**446**)

Hills of the Vermont Station[52] found from 3 trials that when cows were fatigued by being driven a long distance or shipped by rail the flow of milk was lessened temporarily. In some cases the fat content of the milk was decreased and in others increased. Hills points out the folly of testing cows after transferring to new quarters and before they have become rested and accustomed to their surroundings.

In trials in Germany[53] grooming cows caused an increase of 4 to 8 per ct. in the flow of milk. Hills of the Vermont Station[54] found no such increase in yield due to grooming. However, in the Vermont trial the ungroomed cows were never allowed to become so filthy as they do on many farms in winter. Tho grooming may not increase the yield of milk, it does improve its quality by lessening the bacterial content and is also said to improve the health of the animals.

569. Dehorning, tuberculin testing, and spaying.—Woll and Humphrey of the Wisconsin Station,[55] studying the results at 11 experiment stations, conclude that dehorning dairy cows causes a temporary loss of about 8 per ct. in yield of milk and only an insignificant loss in yield of butter fat. This is repaid a hundred fold in greater comfort of the herd thereafter. The wise dairyman will agree with Beach of the Connecticut (Storrs) Station[56] who writes after dehorning the Station herd: "The worry, pain, and cruelty of animals to their mates is eliminated when these instruments of torture are removed, and the lack of fear and the quiet contentment of the individuals of the herd are at once noticeable. The benefits from dehorning dairy cattle cannot be accurately measured, but there is an almost unanimous opinion in its favor among those who have practiced it in their herds."

Studies at the Wisconsin Station[57] show that subjecting cows to the tuberculin test has practically no effect on the yield of milk and butter fat.

Spaying has sometimes been recommended in the case of cows which are not to be retained as breeders, it being held that not only is the milk

[51] Molkerei Zeitung, 17, 1903, p. 191.
[52] Vt. Rpt. 1907.
[53] Backhaus, Jour. Landw., 41, 1893, p. 332.
[54] Vt. Rpts. 1899, 1900.
[55] Wis. Rpt. 1905.
[56] Conn. (Storrs) Rpt. 1902.
[57] Wis. Rpt. 1905.

of spayed cows richer but that the lactation period is also lengthened 12 to 15 months. Nicolas,[58] after continued experiments with spayed and unspayed cows, concludes that such practice is not warranted by the results. The quality of the milk from spayed cows is better than that of non-pregnant cows, but poorer than that of the pregnant cows.

570. Milking machines.—Because of the difficulty of securing efficient hand milkers, the use of milking machines attracts wide-spread interest. The various types of machines have now been improved and long-continued trials at various stations[59] show that when cows are milked with the best machines by careful operators and with well-adjusted teat cups there is no injurious effect on the yield or quality of the milk, or on the health of the animals. While with most cows the machine does not draw quite all the milk from the udder and it is necessary to strip by hand, nevertheless a considerable saving in time results from the use of machines. Hooper and Nutter of the Kentucky Station[60] found at the Elmendorf dairy that 2 men required 3 hours to milk 50 cows by hand, aided by a boy to carry the milk to the milk house. Using 2 units per man the men, aided by the boy as before, milked these cows in 1 hour and 15 minutes. Later, using 3 units per man, the 2 men alone milked the cows in 1 hour and 45 minutes. When the machines are properly cleansed and the rubber tubing kept in an antiseptic solution, the sanitary condition of the milk is improved over that ordinarily obtained by hand milking. Owing to the first cost of the machines and the labor involved in their operation and cleansing, various authorities consider machine milking economical under usual conditions only where at least 15 to 30 cows are milked thruout the year.

571. Regularity and kindness.—For the best results with dairy cows, as with other farm animals, they should be treated with kindness at all times, and regularity in feeding and care should be observed. Many of the highest yielding cows are of nervous temperament, and especially with such animals any excitement usually causes a sharp decrease in yield. Hence cows being driven should not be hurried and attendants should never strike or otherwise abuse them. Changes in the daily routine which do not unduly disturb cows apparently have no great effect on their yield. Carlyle of the Wisconsin Station[61] found that changing milkers had no appreciable effect upon the yield of milk or fat. Linfield[62] concludes that any change in milk yield is due to the individuality of the milker and not to the mere change of the milkers. Grisdale of the Ottawa Experimental Farms[63] found that irregularity in the intervals between milkings slightly reduced the quantity and quality of the milk.

[58] Soc. de L'Aliment. Rationelle du Betail, 1898.

[59] Mairs, Penn. Bul. 85; Price, Tenn. Bul. 80; Haecker and Little, Nebr. Bul. 108; Woll and Humphrey, Wis. Res. Bul. 3, also Bul. 173; McMillan, Agr. Gaz., N. S. Wales, 22, 1911, pp. 859–868; Smith and Harding, N. Y. (Cornell) Bul. 353; Larsen, White, and Fuller, S. D. Bul. 144; Hooper and Nutter, Ky. Bul. 186.

[60] Ky. Bul. 186. [61] Wis. Rpt. 1903. [62] Utah Bul. 68.

[63] Ottawa Expt. Farms, Rpts. 1901, 1902.

When the changes were not sudden, the effect due to the difference in the length of the intervals between the milkings was negligible.

572. Minor Points.—Lane of the New Jersey Station[64] found that cows receiving 3 feeds daily consumed more roughage and gave slightly more milk than those getting 2 daily, but the increase barely paid for the extra labor and feed. Grisdale of the Ottawa Experimental Farms[65] found 2 feeds as effective as 3 in maintaining the milk flow. It is reasonable to hold that 2 generous feeds daily are sufficient for the dairy cow with her roomy digestive apparatus. (**35**)

On feeding cows wet and dry concentrates, Grisdale[66] found a small difference in favor of the dry feed.

Hills of the Vermont Station[67] holds that it does not usually pay to milk cows thrice daily, tho a temporary increase in milk flow is produced thereby. Dean of the Ontario Agricultural College[68] concludes that such practice is not profitable except perhaps in the case of very heavy milkers.

The ''Hegelund method'' consists in so manipulating the cow's udder after milking as to bring down all remaining traces of milk. By this system, Woll of the Wisconsin Station[69] found that the daily milk yield of a herd of 24 cows was increased 4.5 per ct. and the fat yield 9.2 per ct. The average daily gain per cow of 1 lb. of milk and nearly 0.1 lb. of fat seemed to be maintained thruout the whole lactation period. Wing and Foord at the New York (Cornell) Station[70] found no advantage in this method over thoro stripping by the ordinary method.

Woodward, Turner, and Curtice of the United States Department of Agriculture[71] found that when cows which were immune to tick fever were infested with ticks the milk yield was reduced 34.2 per ct. on account of the depletion of the blood. In tick infested districts they advise spraying or dipping with an arsenical solution, at least when animals are heavily infested.

573. Flavor, odor, and color.— Milk and its products possess qualities cognizable only to sight, taste, and smell. The Guernsey breed excels in producing a milk with a yellow fat. Pasture grass, soiling crops, carrots, and some other feeding stuffs impart a yellowish tinge to milk fat. Due to minute quantities of volatile oils they contain, onions, leeks, turnips, rape, etc., impart an objectionable flavor to milk, possibly apparent to all people, while other flavors are detected by some but pass unnoticed by many. When cows are first turned to pasture, we at once observe a grass flavor in the milk and butter, tho it soon disappears; but whether it has really disappeared or we only fail to notice it, we do not know. It is possible that after a time the cow more completely eliminates such volatile oils than at first. Bad flavors can be largely avoided by

[64] N. J. Rpt. 1900.
[65] Ottawa Expt. Farms, Rpt. 1904.
[66] Ottawa Expt. Farms, Rpt. 1901.
[67] Vt. Rpt. 1907.
[68] Ont. Agr. Col., Rpt. 1898.
[69] Wis. Rpt. 1902.
[70] N. Y. (Cornell) Bul. 213.
[71] U. S. Dept. Agr. Bul. 147.

feeding whatever causes them immediately after milking so that the volatile oils they furnish, which are the source of the trouble, may the more completely escape from the body before the next milking.

It is further possible that the facility with which flavors and odors pass from feed to milk or are eliminated from the body when once within it varies with different cows. The flavors and aroma of butter are mostly due to fermentation of milk sugar, so that this matter rests only in part on feeding.

Sometimes when a cow is far along in lactation her milk grows bitter and distasteful. Eckles[72] states that so far as he has observed this occurs only when the animal is far advanced in pregnancy and rarely happens when green feed is supplied. He writes that reducing the grain ration and giving 2 or 3 doses of Epsom salts may remove the trouble.

It is probable that the milk of every cow, aside from the influence of feed, possesses a distinctly individual flavor too delicately fine to be observed by most humans, but plainly noticed by others. It may be that in the future, when the grosser problems now perplexing dairymen have been solved, it will be found that certain cows yield a peculiarly palatable milk. Should this prove to be the case, then thru selection there may be established breeds or families possessing this ultra-refined and most desirable quality.

The whole subject of odors and flavors in milk and dairy products is greatly complicated by the fact that there is a wide range in the ability of different individuals to detect and distinguish them. Flavors and odors plainly evident to one person are unnoticed by another. Often odors and flavors charged to feed or cow are due to contamination of the milk in the stable or elsewhere, after it is drawn from the cow.

574. The yellow color of cream and butter.—It is common knowledge that cows produce cream and butter which is more deeply colored in summer when eating green feeds than in winter, and that Jerseys and Guernseys usually produce a yellower product than the other breeds. Extensive investigations by Palmer and Eckles at the Missouri Station[73] have at length shown the cause of yellow color in butter fat. They find that the color is due to a substance called carotin, so named because it is the coloring matter of the carrot. This compound is commonly found in green plants along with the green chlorophyll, which masks its color. (8) It was found that animals given feeds poor in carotin for long periods invariably produced white cream and butter fat, regardless of the breed. This shows that the yellow color of Jersey and Guernsey butter is not due to any ability of these breeds to manufacture carotin. However, when cows of these breeds are given feeds rich in carotin they transfer to their milk a larger part of the yellow coloring matter of the feed than do cows of the other breeds, and hence produce yellower butter fat. Green feeds in general were found to be rich in carotin, as well

[72] Dairy Cattle and Milk Production, p. 227.

[73] Mo. Res. Buls. 9, 10, 11, 12; also Cir. 74.

as hay of a bright green color and new corn silage. Carrots and other yellow roots also contain much of this coloring matter. On the other hand, bleached hay, dry corn fodder or stover, straw, old corn silage in which the carotin had been destroyed by fermentation, corn, both yellow and white, and all the common concentrated by-products, such as wheat bran, linseed meal, brewers' grains, etc., were found to be poor in carotin. This explains why cows usually produce light-colored butter in winter. The color of yellow corn is due to a colored substance other than carotin, which does not pass into the milk.

The yellow color of the body fat and skin of Jerseys and Guernseys was found to be due to carotin. This shows why cows of these breeds yield a highly colored product for a long time after going on winter feed. During such periods the yellow coloring matter in their body fat is transferred to the milk. Purchasers often discriminate against beef having deeply colored fat, yet this tallow is colored by the same substance that gives butter the highly desired yellow color.

CHAPTER XXII

FEEDS FOR THE DAIRY COW

I. Carbonaceous Concentrates

With the high prices now ruling for feed and labor, studies of the cost of milk production reveal that on many farms, even where dairy cows of good quality are kept, milk is being produced at little or no profit to the owner. Yet by a wise selection of feeds and intelligent feeding other dairymen secure goodly profits from cows no better. This shows emphatically that the feeding of the herd must be given most careful study and the system of farming so planned that a ration both well-balanced in chemical nutrients and otherwise satisfactory may be provided at minimum expense.

575. Indian corn.—Thruout the corn belt Indian corn, a grain highly relished by the cow, is usually the cheapest carbonaceous concentrate available for the dairy herd. Owing to its wide nutritive ratio corn should be used as the sole concentrate only when leguminous roughages supply the lacking protein, and even then more variety in the ration is better. (**201**) At the Illinois Station[1] Fraser and Hayden fed 1 lot of 10 cows for 131 days on the well-balanced ration shown in the table, in which gluten feed and clover hay furnished the protein necessary to balance the ground corn and corn silage. Another lot was fed corn as the sole concentrate, with corn silage, timothy hay, and a small amount of clover hay for roughage, as is indicated in the table:

Corn requires supplement for feeding dairy cows

Average ration		Nutritive ratio	Average daily yield Milk Lbs.	Fat Lbs.
Lot I, Balanced ration				
Ground corn, 3.3 lbs.	Clover hay, 8 lbs.			
Gluten feed, 4.7 lbs.	Corn silage, 30 lbs.... ..	1 : 6	30.1	0.96
Lot II, Unbalanced ration				
Ground corn, 8 lbs.	Timothy hay, 5 lbs.			
	Clover hay, 3 lbs.			
	Corn silage, 30 lbs........	1 : 11	20.5	0.69

As soon as Lot II was changed from the excellent ration they had previously been fed to the unbalanced ration shown in the table, which had a nutritive ratio of 1:11, they fell off sharply in production. While the cows in Lot I were seldom off feed, this occurred frequently in Lot II. During the trial the cows in Lot I produced 47 per ct. more milk and 39 per ct. more fat than those in Lot II.

At the Maryland Station[2] Patterson fed cows on corn meal with corn

[1] Ill. Bul. 159. [2] Md. Bul. 84.

fodder and soilage corn as the chief roughages during the entire lactation period, while others were given a well-balanced ration of gluten feed, wheat bran, and corn meal, with the same roughages. The next year the rations were reversed so that each cow was on both sides of the trial. On the unbalanced ration containing corn meal as the sole concentrate the average annual yield of the cows was only 3,150 lbs. of milk or 152 lbs. of butter. When the protein-rich concentrate mixture was fed the yield of milk was increased 33 per ct. and that of butter over 45 per ct. These trials show the folly of expecting profitable production from such unbalanced rations, even tho they may be palatable.

576. Corn meal; corn-and-cob meal.—Corn is commonly ground for the dairy cow (**423**), but sometimes ear or shock corn is fed. When other bulky concentrates are not furnished it may be advisable to feed this grain in the form of corn-and-cob meal. Lane of the New Jersey Station[3] secured 9.4 per ct. more milk when feeding corn-and-cob meal as half the concentrate allowance than when an equal weight, including cob, of ear corn was fed. Cook of the same Station[4] found corn-and-cob meal of slightly lower value than an equal weight of corn meal. (**208**)

577. Hominy feed.—This carbohydrate-rich by-product, quite similar to corn in composition, compares favorably in feeding value with this grain. (**213**) Like corn it must be supplemented by feeds rich in protein.

578. Wheat.—Wheat, which is usually too high priced for feeding except when low in quality, has about the same value for cows as corn. This is shown in a trial by Bartlett at the Maine Station[5] in which 6 cows were fed by the reversal method for three 21-day periods. When 5 lbs. of wheat meal replaced an equal weight of corn meal in the ration the returns in milk and fat were practically unchanged.

At the Copenhagen (Denmark) Station Friis[6] compared ground wheat with a mixture of equal parts of ground barley and oats in trials on 6 farms. When fed with a basal ration of 3.3 lbs. wheat bran, 1.8 lbs. oil cake, 30 lbs. mangels, 10 lbs. hay, and straw without limit, 5.2 lbs. of wheat was fully equal in value to the same weight of mixed barley and oats. Wheat should be ground or preferably rolled for cows. (**215**)

579. Oats.—This grain, which supplies somewhat more protein than does corn or wheat, is an excellent feed for the dairy cow. However, owing to the high price of oats, most dairymen cannot economically use them in any large way. Usually the various concentrate by-products are cheaper sources of crude protein, while corn furnishes carbohydrates at less expense. The value of this grain is well shown in the following table, which presents the results secured by Woll at the Wisconsin Station[7] on feeding 4 cows for 2 alternate 21-day periods on rations of 6 lbs. clover hay and corn stover without limit for roughage, with the concentrate allowances indicated:

[3] N. J. Bul. 84.
[4] N. J. Rpt. 25, pp. 159–167.
[5] Me. Rpt. 1895.
[6] Copenhagen Sta., 34th Rpt., 1895.
[7] Wis. Rpt. 1890.

Ground oats vs. wheat bran for dairy cows

	Average concentrate allowance		Average daily yield Milk Lbs.	Fat Lbs.
I.	Ground oats, 10 lbs.	Corn meal, 2 lbs.	23.3	1.03
II.	Wheat bran, 10 lbs.	Corn meal, 2 lbs.	20.8	0.93

When fed oats in place of wheat bran, the cows produced 12 per ct. more milk and 11 per ct. more fat. It should, however, be remembered that bran is much higher in digestible crude protein than oats and hence will be more efficient than this grain in balancing a ration deficient in this nutrient. Lindsey of the Massachusetts Station[8] found that when fed with a basal ration of 3.2 lbs. bran and 19.1 lbs. mixed hay, 4.5 lbs. oats was equal to the same weight of corn meal for milch cows. (223)

580. Barley.—Barley is fed to dairy cows to a considerable extent in Europe and has a reputation for producing milk and butter of excellent quality. The Danes regard ground barley and oats as one of the best concentrate mixtures for dairy cows. Judging from the composition of barley and the results of trials with other animals (226), it would seem that the value of barley for the dairy cow would be slightly lower than that of corn per pound, but the Scandinavians consider these grains of practically equal value.

581. Rye.—Large allowances of rye produce a hard, dry butter, but about 2.2 to 3.3 lbs. per head daily mixed with other feeds has given good results.[9] At the Pennsylvania Station[10] Hayward fed 3 cows a basal ration of 2.5 lbs. cottonseed meal, 2.0 lbs. linseed meal, and 12 lbs. timothy hay and supplied in addition 3.5 lbs. of either rye meal or corn meal during 3 periods of 35 days each. Four per ct. less milk and 5 per ct. less butter was produced on the ration containing rye, indicating that rye meal is somewhat less valuable than corn meal for the dairy cow. (232)

582. Emmer.—Wilson and Skinner of the South Dakota Station,[11] when feeding brome hay and corn silage for roughage, found that cows produced 1 lb. of butter fat for each 15.5 lbs. of corn or barley meal fed, while 17.5 lbs. of ground emmer (spelt) were required, a difference of 13 per ct. in favor of barley or corn meal. (233)

583. Kafir meal.—In a trial with 18 cows for 7 weeks, Cottrell and Skinner of the Kansas Station[12] found that 8 lbs. of kafir meal and 20 lbs. of alfalfa hay made the cheapest dairy ration for Kansas conditions. When fed with prairie, timothy, or sorghum hay or with corn fodder, kafir tends to dry up the cows, and if fed abundantly to fatten them, as would be expected from the unbalanced nature of the ration. (237)

584. Sorghum meal.—During three 20-day periods Cook of the New Jersey Station[13] fed cows rations composed of 5 lbs. corn stover, 20 lbs. wet brewers' grains, 5 lbs. bran, and 9 lbs. of either corn meal or meal

[8] Mass. Rpt. 1913, Part I, pp. 141–153.
[9] Pott, Handb. Ernähr. u. Futter., II, 1907, p. 451.
[10] Penn. Bul. 52. [11] S. D. Bul. 81. [12] Kan. Bul. 93. [13] N. J. Rpt. 1882.

from seed of sweet sorghum, for each 1000 lbs. live weight. When the sorghum meal ration was fed the yield of milk was about 10 per ct. less than when the corn meal was supplied. (**241**)

585. Dried beet pulp.—This bulky carbonaceous concentrate has become popular with dairymen, especially those feeding cows on forced test, on account of its slightly laxative and cooling effect. At the Massachusetts Station[14] Lindsey found 4.3 lbs. of dried beet pulp equal to the same weight of corn meal when fed with a basal ration of 2.0 lbs. wheat bran, 0.7 lb. cottonseed meal, and 17 lbs. mixed hay. (**275**)

Where silage is not available, dried beet pulp, moistened before feeding, as it should always be when a large allowance is fed, is a satisfactory, tho usually expensive, substitute. This is shown in a trial by Billings at the New Jersey Station[15] in which 2 lots each of 2 cows were fed the rations shown below alternately for two 15-day periods:

Dried beet pulp as a substitute for corn silage

	Average ration	Average daily yield Milk Lbs.	Fat Lbs.
I.	Dried beet pulp, 9 lbs. Mixed hay, 10 lbs. Rich concentrates, 10.5 lbs......	33.6	1.39
II.	Corn silage, 45 lbs. Mixed hay, 5 lbs. Rich concentrates, 10.5 lbs......	30.2	1.25

Where 9 lbs. of dried beet pulp and 5 lbs. mixed hay replaced 45 lbs. of corn silage, the cows gave 11 per ct. more milk and butter.

586. Dried molasses-beet pulp.—Billings of the New Jersey[16] and Lindsey of the Massachusetts Station[17] found dried molasses-beet pulp about equal in feeding value to dried beet pulp for dairy cows. In a trial by Billings dried molasses-beet pulp proved almost as valuable as an equal weight of hominy meal, the cows eating the dried molasses-beet pulp with more eagerness and remaining in better health. The milk from cows fed on dried molasses-beet pulp at first had a sweet taste, which soon passed away. Since both dried beet pulp and molasses-beet pulp are low in protein, they should not be fed as substitutes for protein-rich feeds, as has often been done. (**277**)

587. Whey.—At the Kiel Dairy Station[18] Schrodt fed cows a ration of 11 lbs. clover hay, 5.5 lbs. barley straw, 10 lbs. mangels, 5.5 lbs. wheat bran, and 2.2 lbs. palmnut meal. During one period 11 lbs. of sweet whey was fed, and during another, 22 lbs. The whey had a favorable influence on the quantity of milk yielded, and no deleterious effect on the quality of the butter. (**268**)

II. Protein-Rich Concentrates

588. Wheat bran.—This palatable, bulky concentrate is one of the most esteemed feeds for the dairy cow, for it is quite high in crude

[14] Mass. Rpt. 1913, Part I, pp. 129–140.
[15] N. J. Bul. 189.
[16] N. J. Rpt. 1904.
[17] Mass. Rpt. 1913, Part I, pp. 129–140.
[18] Jahresber. Agr. Chemie, 1882, p. 441.

protein, is rich in phosphorus, and has a beneficial laxative effect on the digestive tract. (218) Owing to its popularity, bran is usually high in price, considering the amount of crude protein it furnishes. Other by-products, such as gluten feed, dried brewers' grains, and cottonseed meal, which are richer in digestible crude protein, are therefore usually more economical sources of protein for balancing the ration. Under many conditions it is accordingly best to feed bran only in limited amount for its beneficial effect on the health of the animals, rather than as the chief source of crude protein in the ration. This concentrate is especially valuable for cows just before and after calving, for those on official test, and for young, growing animals.

In feeding trials with 447 cows on several Danish farms the Copenhagen Station[19] found wheat bran fed as the sole concentrate fully equal to a mixture of equal parts of ground barley and oats. Bran, however, should rarely be so fed, but always in combination with some feed rich in carbohydrates, such as corn, rye, barley, etc., and with some legume roughage to furnish lime, which it lacks. (98)

589. Wheat shorts; wheat middlings; wheat mixed feed.—Tho higher in digestible crude protein than wheat bran, shorts or middlings are less palatable and are heavy, rather than bulky feeds. They should hence be fed to dairy cows only in limited amounts mixed with other concentrates. The Copenhagen Station[20] secured slightly larger returns from wheat shorts than from wheat bran in trials with 240 cows. (220)

On account of its higher content of digestible protein and carbohydrates Smith and Beals of the Massachusetts Station[21] rate the value of a good grade of wheat mixed feed at 10 per ct. more than that of bran.

590. Corn gluten feed.—This by-product, which contains about twice as much digestible crude protein as wheat bran and is not a very heavy feed, is a valuable concentrate for the dairy cow. In a trial at the Vermont Station[22] with 2 cows fed by the reversal method in 18-day periods, Cooke found that when 4 lbs. of gluten feed replaced an equal weight of a mixture of wheat bran and corn meal the yield of milk was increased 15 per ct. and of fat 16 per ct. (210)

591. Gluten meal.—Hills of the Vermont Station[23] fed 6 cows for 20 weeks, comparing gluten meal with a mixture of equal parts of corn meal and wheat bran. He found that 100 lbs. of dry matter in the form of gluten meal, substituted for an equal amount of dry matter in a mixture of equal parts corn meal and wheat bran, increased the yield of milk and total solids 12.5 per ct. (211)

592. Germ oil meal.—In a feeding trial with 4 cows at the Vermont Station[24] Hills compared a mixture of equal parts of germ oil meal and wheat bran with one composed of 1 part cottonseed meal, 1 part linseed meal, and 2 parts wheat bran. In a second trial the germ oil meal and

[19] Copenhagen Sta., Rpt. 1894.
[20] Copenhagen Sta., Rpt. 1894.
[21] Mass. Bul. 146.
[22] Vt. Rpt. 1892.
[23] Vt. Rpt. 1895.
[24] Vt. Rpt. 1901.

bran mixture was compared with ground oats. The roughage consisted of mixed hay and corn silage. In both trials the returns were in favor of the germ oil meal. (**212**)

593. Dried brewers' grains.—To compare the value of dried brewers' grains and wheat bran Lindsey of the Massachusetts Station[25] fed a lot of 4 cows and one of 3 cows by the reversal method for two 28-day periods. All were given a daily roughage allowance of 26.2 lbs. corn silage and about 12.4 lbs. bluegrass hay, with concentrates as shown below:

Dried brewers' grains vs. wheat bran for dairy cows

Average concentrate allowance			Average daily yield Milk Lbs.	Fat Lbs.
I.	Dried brewers' grains, 4.3 lbs.	Gluten feed, 3.0 lbs..	21.4	1.1
II.	Wheat bran, 4.4 lbs.	Gluten fed, 3.0 lbs..	20.8	1.1

The results show dried brewers' grains somewhat superior to wheat bran for milk production. Hills of the Vermont Station[26] found dried brewers' grains and wheat bran equal in feeding value to a mixture of cottonseed meal, linseed meal, and wheat bran. (**228**)

594. Malt sprouts.—Tho not especially palatable, malt sprouts may be successfully fed to dairy cows when mixed with other feeds, and are often a cheap source of protein. When over 2 lbs. daily is fed, they should be soaked before feeding in order to avoid digestive disturbances, as they swell greatly on absorbing water.

Lindsey of the Massachusetts Station[27] fed 2 lbs. malt sprouts against 1.5 lbs. gluten feed to cows getting a basal ration of 10 lbs. of Kentucky bluegrass hay, 10.4 lbs. rowen hay, 2 lbs. wheat bran, and 1 lb. corn meal, with the following results:

Malt sprouts vs. gluten feed for dairy cows

Average ration			Average daily yield Milk Lbs.	Fat Lbs.
Ration I.	Malt sprouts, 2.0 lbs.	Basal ration.............	18.1	0.89
Ration II.	Gluten feed, 1.5 lbs.	Basal ration.............	18.2	0.91

It will be seen that 2 lbs. of malt sprouts were about equal to 1.5 lbs. of gluten feed. Lindsey[28] states that an excess of malt sprouts should be avoided as they are deficient in lime and also may cause abortion when fed in large amounts. According to Pott[29] feeding over 3.3 lbs. per head daily may impart an aromatic, bitter taste to the milk. When making up half to two-thirds the concentrate allowance Hills of the Vermont Station[30] found malt sprouts of lower value than oats. (**230**)

595. Buckwheat middlings.—Hills of the Vermont Station[31] reports that cows fed buckwheat middlings produced 8 to 11 per ct. more milk

[25] Mass. Bul. 94.
[26] Vt. Rpt. 1903.
[27] Mass. Bul. 94.
[28] Mass. Rpt. 1911, Part II, p. 83.
[29] Handb. Ernähr. u. Futter., III, 1909, p. 225.
[30] Vt. Rpt. 1902.
[31] Vt. Rpts. 1900, 1907.

than on an equal weight of a mixture of equal parts corn and wheat bran. When fed as the sole concentrate, the cows did not usually relish buckwheat middlings, and the quality of the butter was somewhat impaired. Hayward and Weld of the Pennsylvania Station[32] found buckwheat middlings and dried brewers' grains equally valuable for dairy cows when judiciously fed as part of a balanced ration. When thus fed neither of these feeds had a detrimental effect upon the flavor or quality of the milk or butter. (**244**)

596. Cottonseed meal.—Experience has shown that cottonseed meal may be fed to dairy cows in properly balanced rations for years with no ill effects. This is most fortunate since this highly nitrogenous feed is usually the cheapest source of protein in the South and often likewise in the North. Since cottonseed meal is constipating it should be fed with laxative concentrates, such as linseed meal or wheat bran, or with succulent feed, such as silage or roots. The milk of cows heavily fed on cotton seed or cottonseed meal yields a hard, tallowy butter, light in color and poor in flavor. If a moderate allowance is fed in a properly balanced ration the quality is not impaired and may even be improved if the other feeds tend to produce a soft butter. (**562**) This feed is used as the sole concentrate on many southern farms, a practice which is safe when only a limited allowance is given. Soule of the Georgia Station[33] reports that for several years the station dairy herd has been fed 2 to 3 lbs. of cottonseed meal per head daily with Bermuda grass pasture in summer and corn and sorghum silage in the winter with satisfactory results. The custom has been to feed 2 lbs. to a 700- to 800-lb. cow giving 1.5 to 2 gallons of milk and somewhat more to the heavier producers, but rarely is over 3 lbs. of meal fed. Michels and Burgess of the South Carolina Station[34] found cottonseed meal and corn silage by far the cheapest ration available for dairy cows under prevailing conditions.

Since cottonseed meal is a highly nitrogenous, heavy feed, when a large allowance is given the meal should be mixed with feeds which are bulky and lower in crude protein. McNutt of the North Carolina Station[35] found a mixture of equal parts cottonseed meal, dried beet pulp, and dried distillers' grains highly satisfactory when fed with corn silage. A mixture of cottonseed meal, corn meal, and wheat bran was also satisfactory, but more expensive. During 4 years McNutt fed as much as 6 lbs. of cottonseed meal per head daily to large cows for extended periods, without any unfavorable results when it was given in such a mixture as this and with silage for roughage. At the Texas Station[36] in trials lasting 56 days with 18 cows Soule found that 6 lbs. of cottonseed meal fed daily as the sole concentrate proved more effective and gave larger profits than allowances of 7 to 10 lbs. (**250**)

[32] Penn. Bul. 41.
[33] Breeder's Gazette, 62, 1912, p. 217.
[34] S. C. Bul. 131.
[35] Proc. Amer. Soc. Anim. Prod. 1914.
[36] Texas Bul. 47.

597. Cottonseed meal vs. other concentrates.—At the South Carolina Station[37] Michels and Burgess fed 21 cows for 3 alternate 27-day periods on a ration of 32 to 35 lbs. corn silage (all they would consume) with wheat bran and cottonseed meal in addition as is indicated in the following table. In Period II, 5.1 lbs. of cottonseed meal was fed as the sole concentrate, while in Periods I and III, 3.4 lbs. of wheat bran replaced 1.7 lbs. of cottonseed meal.

At the New Jersey Station[38] Lane fed 4 cows for 66 days on a ration of 36 lbs. corn silage and 6 lbs. corn stalks, with either cottonseed meal alone or a mixture of equal parts of wheat bran and dried brewers' grains for the concentrate allowance, as shown in the table:

Cottonseed meal vs. wheat bran and dried brewers' grains

Average concentrate allowance	Average daily yield Milk Lbs.	Fat Lbs.
South Carolina Station		
Cottonseed meal, 5.1 lbs.	16.4	0.71
Wheat bran, 3.4 lbs. Cottonseed meal, 3.4 lbs.	15.9	0.68
New Jersey Station		
Cottonseed meal, 4.5 lbs.	22.7	0.96
Wheat bran, 5 lbs. Dried brewers' grains, 5 lbs.	23.9	0.95

From the South Carolina trial we learn that when 1.7 lbs. of cottonseed meal was replaced by 3.4 lbs. of wheat bran the yield of milk and fat was slightly decreased. In the New Jersey trial, where corn silage and corn stover formed the roughage, 4.5 lbs. of cottonseed meal did not prove quite equal to 10 lbs. of a mixture of wheat bran and dried brewers' grains. Michels concludes that 1 lb. of cottonseed meal is equal to 2 lbs. of wheat bran for milk production, while Moore of the Mississippi Station[39] holds that 1 lb. of cottonseed meal is only equal to 1.5 lbs. of wheat bran.

In a feeding trial with 24 cows lasting 120 days at the Virginia Station,[40] Soule and Fain, comparing cottonseed meal and gluten meal, found that the relative amount of digestible crude protein contained in these feeds was a fair measure of their feeding value.

598. Cold-pressed cottonseed cake; cotton seed.—In a trial with dairy cows Lee and Woodward of the Louisiana Station[41] found cold-pressed cottonseed cake less valuable for milk and butter production than an equal weight of a mixture of two parts of meal and one of hulls. They conclude that the chemical composition of cold-pressed cottonseed cake is a reliable indication of its feeding value. With cottonseed meal at $30 per ton and hulls at $5 they estimate that cold-pressed cottonseed cake is worth $21.65 per ton. (**248**) Moore of the Mississippi Station[42] found 100 lbs. of cottonseed meal equal to 171 lbs. of cotton seed in feeding value for dairy cows. (**245**)

[37] S. C. Bul. 117.
[38] N. J. Rpt. 1903.
[39] Miss. Bul. 70.
[40] Va. Bul. 156.
[41] La. Bul. 110.
[42] Miss. Bul. 60.

599. Linseed meal.—This slightly laxative, cooling, nitrogenous concentrate is one of the best dairy feeds, but owing to its popularity is often too high in price to furnish protein as cheaply as some of the other feeds which are usually available. Even then 1 to 2 lbs. per head daily is often advisable on account of its tonic and laxative effect, especially with cows out of condition or those soon to freshen.

To compare the value of linseed and cottonseed meal Waters and Hess conducted a trial at the Pennsylvania Station[43] with 9 cows fed for 2 alternate 30-day periods. The cows were fed 9.3 lbs. corn stover per head daily with the concentrate allowances shown in the table:

Linseed vs. cottonseed meal for dairy cows

	Average concentrate allowance		Average daily yield Milk Lbs.	Fat Lbs.
I.	Linseed meal, 6.0 lbs.	Chopped wheat, 6.0 lbs......	15.1	0.78
II.	Cottonseed meal, 5.3 lbs.	Chopped wheat, 6.7 lbs......	16.2	0.77

The cows receiving the cottonseed meal produced somewhat more milk but no more fat than those getting linseed meal. Hills of the Vermont[44] and Michels of the North Carolina Station[45] also found cottonseed meal of slightly higher value than linseed meal as a source of protein. Michels concludes, however, that no farmer should hesitate to use a small amount of linseed meal at any time for animals whose health will be benefited thereby. Linseed meal tends to produce a soft butter and therefore may sometimes be advantageously fed in rations which would otherwise produce a tallowy product. (**254**)

600. Soybeans.—The relative value of ground soybeans and cottonseed meal for milk production was tested by Price at the Tennessee Station[46] with 2 lots each of four 2- and 3-year old heifers, fed the following rations alternately during three 30-day periods:

Ground soybeans vs. cottonseed meal for dairy cows

Average ration		Average daily yield Milk Lbs.	Fat Lbs.
Ration I			
Ground soybeans, 2.3 lbs.	Corn silage, 24.7 lbs.		
Corn-and-cob meal, 2.3 lbs.	Alfalfa hay, 10.3 lbs........	14.4	0.81
Ration II			
Cottonseed meal, 2.3 lbs.	Corn silage, 23.5 lbs.		
Corn-and-cob meal, 2.3 lbs.	Alfalfa hay, 10.0 lbs........	13.6	0.77

It is shown that ground soybeans gave slightly better results than cottonseed meal.

At the Massachusetts (Hatch) Station[47] 2 lots of 4 cows each were fed 6 weeks by the reversal method. To a basal ration of hay, silage, and bran, an allowance of either ground soybeans or cottonseed meal was added in practically equal amounts. The ground soybeans proved

[43] Penn. Rpt. 1895. [45] N. C. Rpt. 33, 1910, p. 29. [47] Mass. (Hatch) Rpt. 1894.
[44] Vt. Rpt. 1907. [46] Tenn. Bul. 80.

slightly superior to the cottonseed meal as a milk and fat producer, and the butter was of better quality.

Cook of the New Jersey Station[48] found 3.4 lbs. of ground soybeans slightly superior to the same weight of cottonseed meal when fed with 3.4 lbs. corn-and-cob meal and 2.3 lbs. dried beet pulp with silage, soilage, and hay for roughage.

Otis of the Kansas Station[49] found that when soybeans formed one-half the concentrates, the butter from such feeding was so soft that it was impossible to work it satisfactorily even tho chilled with ice water. This can be prevented by the addition to the ration of cottonseed meal, which tends to produce hard butter. (**256**)

601. Soybean cake.—Gilchrist[50] of the Armstrong College, England, found soybean cake slightly superior to cottonseed cake for milk production. In an experiment lasting 6 weeks Hansen of the Royal Agricultural Academy, Germany,[51] found soybean cake and linseed cake of practically equal value for milk production when added to a basal ration of hay, bran, and sugar-beet chips. Tho a daily allowance of 4 to 7 lbs. of soybean cake was fed, no ill effects resulted.

Lindsey of the Massachusetts Station[52] found that soybean meal from which the oil had been extracted did not modify the composition of the milk nor exert a marked influence on the body of the butter. Feeding soybean oil temporarily increased the percentage of fat in the milk and produced a softer, more yielding butter.

In view of the vast importance of the soybean in the Orient and its rapidly increasing use in Europe and America, these trials are significant and suggestive. (**257**)

602. Cocoanut meal.—Lindsey of the Massachusetts Station[53] reports that when fed with a basal ration of 20 lbs. mixed hay and 3.5 lbs. wheat bran, 3.7 lbs. of cocoanut meal produced substantially the same amount of milk as when an equal weight of gluten feed was fed. The yield of butter fat was 6 per ct. greater on the cocoanut meal ration, possibly due to the oil in the meal causing a more or less temporary increase in the fat content of the milk, a finding also reported by European investigators. (**562**) Scott of the Florida Station[54] concludes from a feeding trial that a unit of protein from cocoanut meal is nearly, tho not quite, equal to a unit of protein in cottonseed meal for milk production. A limited amount of cocoanut meal produces a firm butter of excellent quality, but when fed in excess of 3 to 4 lbs. per head daily it may make too hard a butter. (**260**)

603. Mixed oil cakes vs. grain.—European dairymen make wide use of the various oil cakes, employing not only cottonseed, linseed, soybean, and cocoanut cake, but also such by-products as palm-nut, sunflower-

[48] N. J. Rpt. 1913, pp. 293–316.
[49] Kan. Bul. 125.
[50] Mark Lane Express, 100, 1909, p. 667.
[51] Deutsche Land. Presse, 36, 1909.
[52] Mass. Rpt. 1908.
[53] Mass. Bul. 155.
[54] Fla. Bul. 99.

seed, hemp-seed, and rape-seed cakes, which are practically unknown to American feeders. In trials with 240 cows on Danish farms the Copenhagen Station found that when a mixture of equal parts by weight of palm-nut, rape-seed, and sunflower-seed cake was substituted for the same amount of mixed barley and oats there was a marked gain in yield of milk, provided the oil-cake mixture did not form more than half the concentrate allowance. For every 100 lbs. of oil-cake which was substituted in the ration, there was a gain of 66 lbs. of milk. These trials well illustrate the high value of oil cakes and meals for milk production.

604. Velvet bean.—Scott of the Florida Station[55] found that cows produced as much milk when fed a ration of 4.3 lbs. velvet beans in the pod, 10 lbs. wheat bran, and 24.5 lbs. Japanese cane silage as when given a ration of 3 lbs. cottonseed meal, 10 lbs. bran, and 34 lbs. cane silage. Hence 4.3 lbs. of velvet beans in the pod were fully equal to 3 lbs. of cottonseed meal. Scott reports that the Florida farmer can produce about 5 tons of velvet beans in the pod for the cost of 1 ton of cottonseed meal. (**361**)

605. Dried distillers' grains.—Dried distillers' grains, which are about as bulky as wheat bran, are extensively employed for feeding dairy cattle. Lindsey of the Massachusetts Station[56] compared this concentrate with gluten feed in trials with 6 cows, covering 2 alternate periods of 4 weeks each. The following table shows the concentrate allowance fed during each period, the roughage thruout the trial consisting of 10.7 lbs. bluegrass hay and 10.7 lbs. rowen hay per head daily:

Dried distillers' grains vs. gluten feed

	Average concentrate allowance		Average daily yield Milk Lbs.	Fat Lbs.
I.	Dried distillers' grains, 3.7 lbs.	Wheat bran, 3.0 lbs.	25.8	1.23
II.	Gluten feed, 3.7 lbs.	Wheat bran, 3.0 lbs.	24.3	1.18

The ration containing dried distillers' grains produced 6 per ct. more milk than that containing the gluten feed. Hills[57] of the Vermont Station similarly found that dried distillers' grains produced 5 per ct. more product than dried brewers' grains. A mixture of 1 part wheat bran and 2 parts dried distillers' grains produced 4 per ct. more milk and fat than did dried distillers' grains alone. Dried distillers' grains produced one-eighth more milk and one-sixth more fat than a mixture of equal parts of corn meal and bran. Dried distillers' grains and cottonseed meal proved equally efficient. Dried distillers' rye grains made less milk and butter than did the alcohol grains. Armsby and Risser of the Pennsylvania Station[58] found that the substitution of dried distillers' grains for an equal weight of a mixture of 3 lbs. of cottonseed meal and 2.5 lbs. of corn meal caused a slight increase in the milk yield. The butter from the distillers'-grains ration was not quite as high in quality

[55] Fla. Bul. 114. [56] Mass. Bul. 94. [57] Vt. Rpt. 1907. [58] Penn. Bul. 73.

as that from the cottonseed meal ration. On the other hand, Billings of the New Jersey Station[59] reports that the butter from cows fed dried distillers' grains was firm, of good flavor and texture, and very marketable. (282)

Hooper of the Kentucky Station[60] states that some cows must become accustomed to the slightly sour smell and taste of dried distillers' grains before they will eat large allowances. While some cows would readily consume 4 lbs. per head daily when mixed with corn meal, it was necessary to mix the grains with silage to get others to consume them at all.

606. Cereal by-products vs. pure grains.—To determine whether the digestible matter in such by-products as dried brewers' grains, malt sprouts, and gluten feed are as valuable as the digestible matter of the pure grains, Jordan and Jenter of the New York (Geneva) Station[61] fed the following rations to 2 lots each of 5 cows for 9 weeks:

Comparison of grains and cereal by-products for milk production

Average ration		Digestible nutrients eaten daily	Daily yield of milk solids	Dig. nutrients eaten for 1 lb. milk solids
		Lbs.	Lbs.	Lbs.
Ration I				
Ground oats, 5 lbs.	Timothy hay, 5 lbs.			
Ground peas, 6 lbs.	Corn silage, 40 lbs..	15.3	2.7	5.6
Ration II				
Malt sprouts, 2 lbs.				
Dried brewers' grains, 3 lbs.	Timothy hay, 15 lbs.			
Gluten feed, 3 lbs.	Corn silage, 25 lbs.	14.1	2.7	5.2

The table shows that the ration containing malt sprouts, brewers' grains, and gluten feed was rather more efficient for milk production than one of oats and peas, containing slightly more digestible matter.

607. Skim milk.—Beach and Clark of the Connecticut (Storrs) Station[62] found that when sweet separator skim milk was offered to the herd of 24 cows, only 4 would drink it, even tho water was withheld for 48 hours and grain was mixed with the milk. Skim milk was substituted for half the grain in the ration at the rate of 8 lbs. of milk for 1 of concentrates, and about 1 ton of milk was fed to each of the 4 cows. Feeding the skim milk caused a small increase in milk flow and a saving of grain, which, taken together, gave to the milk so fed a value of 19 cents per cwt., which is less than pigs would have returned. (266)

608. Blood meal; flesh meal; fish scrap.—*Blood meal* proved equal to twice the weight of cottonseed meal in a trial by Lindsey at the Massachusetts Station[63] in which cows were fed either 1.1 lbs. of blood meal or 2.2 lbs. of cottonseed meal with a basal ration of 4 lbs. hominy meal, 3 lbs. wheat bran, and 20 lbs. of mixed clover and bluegrass hay. The blood meal produced no objectionable flavor in the milk and when mixed

[59] N. J. Rpt. 1907.
[60] Ky. Bul. 171.
[61] N. Y. (Geneva) Bul. 141.
[62] Conn. (Storrs) Rpt. 1904.
[63] Mass. Rpt. 1909, II, pp. 153–157.

with the other concentrates was readily consumed. Lindsey believes that the allowance should be restricted to 1 or 2 lbs. per head daily. (**271**)

Dairy cows may be accustomed to eating *flesh meal,* which is somewhat similar to the tankage or meat meal of this country, by mixing a small amount with well-liked concentrates. European investigators do not recommend feeding over 2.2 to 2.8 lbs. daily per 1,000 lbs. live weight. In a trial by Schrodt and Peters, bran and rape cake were gradually replaced by equal quantities of flesh meal until the allowance of the latter reached 2.2 lbs. per head daily.[64] The cows learned to relish the meal and the yield of milk and fat was increased. (**270**)

Fish meal from which the fat had been extracted proved equal to cottonseed meal in trials by Isaachsen[65] with 20 cows. Kühn[66] states that a daily allowance of 2.3 lbs. of fish scrap produced no deleterious effect on the milk. (**272**)

III. Hay from the Legumes

609. Legume hay for the dairy cow.—Almost everywhere in America the Indian-corn plant provides the cheapest, most abundant, and most palatable carbohydrates the farmer can produce, but it falls short in furnishing protein, so vital in milk production. Happily, at least one of the legumes—alfalfa, clover, cowpeas, or vetch—can be grown on every American farm to supply the deficiency. The dairyman who grows great crops of corn for silage must also have broad fields of clover, alfalfa, or some other legume to help round out the ration. High in crude protein and mineral matter, especially lime, the legume hays are of great importance in reducing the amount of expensive protein-rich concentrates needed to provide a properly balanced ration for the dairy cow. The following articles show that when an abundance of legume hay of good quality and silage from well-matured corn is supplied, but half as much concentrates need be fed as when only carbonaceous roughages are used. Indeed, for cows of moderate productive capacity a ration of legume hay and corn or sorghum silage alone is often the most economical ration that can be furnished. Tho the milk yield may be reduced somewhat on such a ration, an animal of this kind may not pay for the addition of any concentrates. When legume hay is fed to dairy cows it is desirable that some succulent roughage such as corn silage or roots form a part of the ration to furnish variety and palatability as well as nourishment.

610. Alfalfa hay.—Good alfalfa hay is generally placed at the head of the list of roughages suitable for the dairy cow, on account of its high content of protein and its palatability. The value of this hay in balancing

[64] Fühl. Landw. Ztg., 1892, p. 836.

[65] Ber. Norges, Landbr. Hoiskoles Virks, 1910–11, pp. 13–33; Expt. Sta. Rec. 28, p. 363.

[66] Jahresber. Agr. Chem., 1894, p. 482.

rations otherwise low in protein is shown in a trial by Caldwell at the Ohio Station[67] in which 2 lots each of 6 cows were fed the rations shown below for 56 days:

Alfalfa hay as source of protein for dairy cows

Average ration		Average daily yield Milk Lbs.	Fat Lbs.	Nutritive ratio
Lot I				
Alfalfa hay, 11.6 lbs.				
Corn silage, 27.8 lbs.	Corn meal, 5.9 lbs......	22.0	0.87	1 : 7.0
Lot II				
Corn stover, 5.6 lbs.	Cottonseed meal, 3.1 lbs.			
Corn silage, 29.3 lbs.	Wheat bran, 3.1 lbs.			
	Corn meal, 3.1 lbs......	20.5	0.90	1 : 5.7

The ration fed Lot I—alfalfa hay, corn silage, and corn meal—would undoubtedly have been improved had a greater variety of concentrates been fed, yet with alfalfa hay as the sole supplement, a well-balanced ration was provided which produced substantially as good results as that fed Lot II, in which wheat bran and cottonseed meal furnished most of the protein. While Lot II was fed 9.3 lbs. of rich concentrates, Lot I received only 5.9 lbs. of corn meal.

On account of a wide-spread opinion among dairymen in Utah that first crop alfalfa hay was the highest in feeding value, Carroll of the Utah Station[68] compared first, second, and third crop hay in trials during 2 years. Each crop was cut at the period of early bloom from the same field and was cured in excellent condition. In order that the test might be as much as possible upon the 3 crops of hay, only 0.65 lb. of concentrates was fed to each cow daily for every pound of butterfat she produced per week. The concentrate mixture the first year consisted of equal parts of wheat bran and crushed oats, and the second year of equal parts of wheat bran and chopped barley. The cows were given all the hay they would clean up without waste.

In the trials the advantage of any one crop over the others was found to be almost negligible. Considering the hay actually consumed, the second crop hay had slightly the highest value, but it proved slightly less palatable and a little more was wasted than of the other cuttings. In general, leafy, fine-stemmed, early-cut hay is preferred by dairy cows. (338)

611. Substituting alfalfa hay for part of the concentrates.—Billings at the New Jersey Station[69] and Fraser and Hayden at the Illinois Station[70] conducted trials with dairy cows in which alfalfa hay was substituted for part of the concentrates in the ration, with the results shown in the table:

[67] Ohio Bul. 267. [68] Utah Bul. 126. [69] N. J. Bul. 190. [70] Ill. Bnl 146

Feeding alfalfa hay in place of part of the concentrate allowance

Average ration	Average daily yield		Nutritive ratio
	Milk	Fat	
New Jersey, 2 lots of 4 cows fed two 30-day periods	Lbs.	Lbs.	
Ration I			
Corn stover, 7.0 lbs.			
Corn silage, 40.0 lbs.			
Wheat bran, 4.5 lbs.			
Dried brewers' grains, 4.5 lbs.			
Cottonseed meal, 2.0 lbs.	27.3	1.13	1 : 5.4
Ration II			
Alfalfa hay 14.0 lbs.			
Corn silage, 35.0 lbs.			
Cottonseed meal, 2.5 lbs.	26.3	1.05	1 : 4.5
Illinois, 2 lots of 3 cows fed two 66-day periods			
Ration I			
Corn silage, 30 lbs.			
Clover hay, 6 lbs.			
Corn meal, 6 lbs.			
Wheat bran, 8 lbs.	23.8	1.00	1 : 6.9
Ration II			
Alfalfa hay, 8 lbs.			
Corn silage, 30 lbs.			
Clover hay, 6 lbs.			
Corn meal, 6 lbs.	24.4	0.98	1 : 7.0

In the New Jersey trial 14 lbs. of alfalfa hay in Ration II replaced 8.5 lbs. of the protein-rich concentrates, 5 lbs. of the corn silage, and all the corn stover in Ration I. Yet on this cheaper ration there was a shrinkage of only 1 lb. of milk and 0.08 lb. of fat per head daily.

In the Illinois test, tho 8 lbs. of alfalfa hay in Ration II replaced an equal weight of wheat bran fed in Ration I, Ration II produced slightly more milk and practically as much fat.

612. Substituting alfalfa hay for all the concentrates.—Billings[71] conducted a more drastic trial of the value of alfalfa hay for milk production by replacing all of the concentrate allowance with this hay in the following test with 2 lots each of 4 cows fed for two 60-day periods:

Replacing all the concentrate allowance with alfalfa hay

Average ration		Average daily yield Milk Lbs.	Fat Lbs.	Feed cost per 100 lbs. milk* Cents
Ration I				
Corn stover, 6.8 lbs.	Distillers' grains, 4.6 lbs.			
Corn silage, 40.0 lbs.	Wheat bran, 4.2 lbs.			
	Cottonseed meal, 0.5 lb.	24.6	1.07	83.7
Ration II				
Alfalfa hay, 17.5 lbs.				
Corn silage, 35.0 lbs.	No concentrates	20.4	0.88	94.4

*Cost of feeds per ton: alfalfa hay, $16; corn silage, $3; corn stover, $4; distillers' grains, $30; wheat bran, $24; and cottonseed meal, $34.

[71] N. J. Bul. 204.

In this trial when the cows were fed Ration II, containing a heavy allowance of alfalfa hay but no concentrates, the yield of milk was 17 per ct. and of fat 18 per ct. less than when Ration I, containing over 9 lbs. of purchased protein-rich concentrates, was fed. With feeds at the prices indicated, milk was produced more cheaply on Ration I. The relative economy of such rations obviously depends on the price of alfalfa hay compared with concentrates.

At the Illinois Station[72] Fraser maintained a herd of good productive cows for 6 years exclusively on the alfalfa hay and corn silage grown on 20 acres. The average yield of milk was 3,980 lbs. and of fat 139.5 lbs. per acre. This ration did not maintain the cows in as good health as when concentrates were fed in addition, and undoubtedly a larger and also more economical yield would have been secured had at least a moderate concentrate allowance been supplied.

In a 12-week trial with 8 cows at the New Mexico Station[73] Vernon found that 246 lbs. of alfalfa hay fed alone, or 202 lbs. of alfalfa hay and 49 lbs. of wheat bran, produced 100 lbs. of milk. The cows yielded more milk on the bran-alfalfa ration, but the increase was dearly purchased.

The preceding trials show that alfalfa hay can be substituted for a large part of the concentrates in the ration of the dairy cow without materially reducing the yield of milk or fat. However, when all the concentrates are so replaced the yield of cows of good productive capacity is markedly decreased. This is what we should expect, for alfalfa hay, tho standing at the head of all roughages, is nevertheless a roughage and not a concentrate. It contains about 3 times as much fiber as wheat bran, which is bulky for a concentrate, and furnishes but 70 per ct. as much net energy. Bearing in mind the productive capacity of his cows and the price of legume hay compared with concentrates, each dairyman must decide for himself to what extent it is economical to substitute legume hay for concentrates.

In some sections of the West, owing to the cheapness of alfalfa hay, dairy cows are given this feed alone, possibly with green alfalfa soilage or pasturage in addition during the summer. Complaints are made that this unbalanced ration, which is too high in protein and too low in net nutrients, does not always maintain the animals in as good health as where concentrates or even roughages lower in protein are added.

Woll of the California Station[74] found in trials in which rolled barley was added to an exclusive alfalfa ration that the immediate increase in production resulting from grain feeding was not sufficient with feeds at prevailing prices to pay for the added expense. However, considering the influence on the production during the balance of the lactation period and the effect on the condition of the cows, he believes that the feeding of some grain is advisable, especially in the case of large producing animals or heifers in milk.

[72] Information to the authors.
[73] N. Mex. Rpt. 1904.
[74] Information to the authors.

613. Alfalfa meal.—Hills of the Vermont Station,[75] on substituting alfalfa meal (ground alfalfa hay) for the same weight of wheat bran, found a loss of from 3 to 6 per ct. in milk flow caused thereby, and Mairs of the Pennsylvania Station[76] reports a loss of about 5 per ct. by such substitution. Similar results were secured by Lindsey in a trial at the Massachusetts Station.[77] In view of the palatability of alfalfa hay to the dairy cow and its thoro mastication during rumination, the use of alfalfa meal is ordinarily not economical when good alfalfa hay is available. (**344**)

614. Clover hay.—Hay from the clovers, cut while yet in bloom, is one of the best roughages for dairy cows. Somewhat lower than alfalfa hay in protein, red clover hay furnishes a slightly larger amount of net energy than alfalfa. (**171**) By the use of clover hay—red, alsike, or crimson—the dairyman may reduce the amount of concentrates needed to supply a well-balanced ration in the same manner as has been shown in the case of alfalfa hay. (**347, 350, 353**)

At the New Jersey Station[78] Lane fed 2 lots, each of 2 cows, for two 12-day periods alternately on the rations shown below:

Crimson clover hay fed against purchased protein

Average ration		Average daily yield Milk Lbs.	Average daily yield Fat Lbs.
Ration I			
Crimson clover hay, 16.4 lbs.			
Corn silage, 30.0 lbs.	No concentrates..............	20.1	0.85
Ration II			
Mixed hay, 5.0 lbs.	Wheat bran, 6 lbs.		
Corn silage, 30.0 lbs.	Dried brewers' grains, 5 lbs....	23.8	1.00

The table shows that the yield of milk was 3.7 lbs. and of fat 0.15 lb. less on the crimson clover ration than on that containing purchased concentrates. Using the home-grown ration, however, effected a saving of 18.3 cents in the feed cost of producing 100 lbs. of milk.

615. Crimson clover hay and cowpea silage.—Lane[79] also compared a ration of crimson clover hay, cowpea silage, and corn-and-cob meal with one in which the protein was largely purchased. The following rations were fed alternately for 2 periods of 12 days each to 2 lots of 2 cows each:

Crimson clover hay and cowpea silage compared with purchased protein

Average ration		Average daily yield Milk Lbs.	Average daily yield Fat Lbs.
Ration I			
Crimson clover hay, 10 lbs.			
Cowpea silage, 36 lbs.	Corn-and-cob meal, 6.0 lbs..	24.8	0.94
Ration II			
Mixed hay, 5 lbs.	Dried brewers' grains, 5.0 lbs.		
Corn silage, 36 lbs.	Cottonseed meal, 2.5 lbs.....	24.6	0.99

[75] Vt. Rpt. 1906.
[76] Penn. Bul. 80.
[77] Mass. Rpt. 1909, pp. 158–166.
[78] N. J. Bul. 161.
[79] N. J. Bul. 161.

The amount of milk and fat produced was practically the same for both rations, showing the high value of crimson clover hay and cowpea silage as sources of protein for dairy cows. (**353**)

616. Cowpea hay.—In the South the cowpea vine, thriving on all types of soil, is of great importance to the dairy industry, as it furnishes palatable hay rich in protein. To determine the effect of substituting cowpea hay for protein-rich concentrates Lane[80] fed 2 lots each of 2 cows the rations shown below for 15-day periods:

Cowpea hay compared with purchased protein

	Average ration	Average daily yield Milk Lbs.	Fat Lbs.
Ration I			
Cowpea hay, 17 lbs.			
Corn silage, 36 lbs.	No concentrates..............	23.7	0.92
Ration II			
Corn stover, 5 lbs.	Wheat bran, 4 lbs.		
Corn silage, 36 lbs.	Dried brewers' grains, 3 lbs.		
	Cottonseed meal, 2 lbs.........	25.7	1.05

Tho 2 lbs. more milk and 0.13 lb. more fat were produced by each cow daily on the ration containing purchased concentrates, this increase was not sufficient to offset the greater cost of the purchased feed.

At the Alabama Station[81] Duggar fed 2 lots each of 3 cows for two 30-day periods a basal ration of 9.6 lbs. cottonseed hulls and 9.6 lbs. of a mixture of 2 parts cotton seed and 1 part each of wheat bran and cottonseed meal, with either wheat bran or cowpea hay in addition, as shown below:

Cowpea hay compared with wheat bran

	Average ration		Average daily yield Milk Lbs.	Fat Lbs.
Ration I.	Cowpea hay, 7.8 lbs.	Basal ration..........	17.3	1.13
Ration II.	Wheat bran, 6.1 lbs.	Basal ration...........	16.0	1.02

In this trial the cows getting the cowpea hay averaged 1.3 lbs. more milk daily than those fed wheat bran, showing that where there is a fair supply of rich concentrates it is more economical to complete the ration with some protein-rich roughage, like cowpea hay or silage, than by adding expensive concentrates.

Wing found at the Georgia Station[82] that cowpea hay produced 30 per ct. more milk than cottonseed hulls, a reasonable result when the composition of these feeds is considered. (**357**)

617. Soybean hay.—At the Tennessee Station[83] Price compared soybean straw and ground soybeans, combined in the same proportion as they occur in soybean hay, with alfalfa hay in a trial with 2 lots of 4 cows each. The returns from rations fed alternately during three 30-day periods are shown in the following table:

[80] N. J. Bul. 174. [81] Ala. Bul. 123. [82] Ga. Bul. 49. [83] Tenn. Bul. 80.

Soybean hay vs. alfalfa hay

Average ration		Average daily yield Milk Lbs.	Fat Lbs.
Ration I			
Soybean straw, 7.1 lbs.	Ground soybeans, 3.7 lbs.		
Silage, 25.0 lbs.	Corn-and-cob meal, 3.7 lbs....	17.2	0.98
Ration II			
Alfalfa hay, 12.3 lbs.			
Silage, 24.6 lbs.	Corn-and-cob meal, 3.7 lbs....	15.1	0.80

The table shows that the soybean ration proved more effective than the alfalfa-hay ration.

In trials during 2 years by Caldwell at the Ohio Station[84] a ration of 8.7 lbs. soybean hay, 31.9 lbs. silage, 5.7 lbs. corn meal, and 1.0 lb. of cottonseed meal proved as good as one containing 8.4 lbs. of concentrates (equal parts by weight of wheat bran, cottonseed meal, and corn meal), 7.0 lbs. corn stover, and 32.8 lbs. corn silage. The feed cost of butter fat was 9.5 per ct. lower on the soybean-hay ration. (**358**)

618. Soybean silage and alfalfa hay.—At the New Jersey Station[85] Lane fed 2 lots of 2 cows each for 2 periods of 15 days alternately upon the rations shown below:

Soybean silage and alfalfa hay compared with purchased protein

Average ration		Average daily yield Milk Lbs.	Fat Lbs.
Ration I			
Soybean silage, 36 lbs.			
Alfalfa hay, 8 lbs.	Corn meal, 6 lbs....................	27.2	0.98
Ration II			
Corn silage, 36 lbs.	Wheat bran, 4 lbs.		
Corn stover, 6 lbs.	Dried brewers' grains, 4 lbs.		
	Cottonseed meal, 2 lbs..............	25.7	0.98

The table shows that the yield of fat was the same on these rations, while the home-grown ration with corn meal produced slightly more milk. There was a saving of 1.1 cents per pound of butter when the ration of soybean silage and alfalfa hay was fed.

619. Hairy vetch hay.—Duggar of the Alabama Station[86] substituted 6.6 lbs. of hairy vetch hay for 7 lbs. of wheat bran for short periods, and found substantially no decrease in milk flow. (**359**)

IV. Carbonaceous Roughages

620. Corn fodder.—Tho inferior to corn silage, good corn fodder, especially that from thickly planted corn, is relished by cows and is a satisfactory substitute for hay from the grasses. Rather than being fed as the sole roughage, it should preferably be used with legume hay. To compare the value of corn fodder and timothy hay as the sole roughages Hunt and Caldwell fed 2 lots each of 4 cows for 45 days at the Pennsylvania Station.[87] Each cow was given 3 lbs. of ground oats and 3 lbs. wheat bran daily, with either corn fodder or timothy hay as shown in the table:

[84] Ohio Bul. 267. [85] N. J. Bul. 174. [86] Ala. Bul. 123. [87] Penn. Rpt. 1892.

Corn fodder vs. timothy hay for dairy cows

Average roughage allowance	Average daily yield Milk Lbs.	Fat Lbs.	Gain or loss in weight Lbs.
Lot I, Corn fodder, 22.8 lbs.	16.2	0.66	—23
Lot II, Timothy hay, 22.3 lbs.	17.1	0.64	+84

Lot I, fed corn fodder, produced less milk but slightly more fat than Lot II, fed timothy hay, and lost in weight while Lot II gained. Taking all the facts into consideration, the fodder corn proved almost as valuable as the same weight of timothy hay. Two tons of timothy hay per acre is a high return, while the yield of the fodder corn used in this trial was nearly 4.5 tons per acre, or over twice that of the timothy hay. The high value of fodder corn for the dairy cow is thus apparent. (294)

621. Corn fodder with alfalfa hay.—The value of corn fodder when fed with legume hay is shown in the following summary of 4 trials by Linfield at the Utah Station[88] in which cows were fed 3 lbs. of wheat bran and 3 lbs. of either wheat, barley, or corn meal, with alfalfa hay or both corn fodder and alfalfa hay for roughage:

Alfalfa hay and corn fodder vs. alfalfa hay

Average roughage allowance	Average daily yield Milk Lbs.	Fat Lbs.
I. Corn fodder, 8.7 lbs. Alfalfa hay, 11.5 lbs.	16.9	0.75
II. Alfalfa hay, 21.5 lbs.	17.1	0.74

It is seen that when fodder corn replaced nearly half of the alfalfa hay, about as good returns were secured as when alfalfa hay alone constituted the roughage. Where corn and alfalfa flourish, both should be used rather than alfalfa alone. (609)

622. Corn stover vs. mixed and clover hay.—At the Wisconsin Station[89] the senior author conducted 2 trials to compare corn stover with mixed hay and with clover hay. A crop of dent corn yielding 4,490 lbs. of cured stalks and 4,941 lbs. of ear corn per acre was cut and shocked in the usual manner. After curing, the corn was husked and the stover reserved for feeding. In both trials 2 lots of 2 cows each were fed by the reversal method for 2 periods each of 3 weeks. All were fed 5 lbs. of corn and 7 lbs. of bran per head daily, with either hay or uncut corn stover as indicated in the table:

Corn stover vs. mixed and clover hay

Average roughage allowance	Average daily yield Milk Lbs.	Butter Lbs.
First trial		
I. Corn stover, 42.4 lbs.	20.0	1.02
II. Mixed clover and timothy hay, 13.5 lbs.	19.0	1.00
Second trial		
I. Corn stover, 33.3 lbs.	19.3	0.93
II. Clover hay, 11.5 lbs.	18.9	0.97

[88] Utah Bul. 68.

[89] Wis. Rpt. 1884.

In the first trial 42.4 lbs. of uncut corn stover was slightly superior to 13.5 lbs. of mixed hay, and in the second 11.5 lbs. clover hay produced somewhat more butter than 33.3 lbs. uncut corn stover. Reduced to tons, we may conclude that 1 ton of mixed clover and timothy hay is worth 3 tons of uncut corn stover, and that 1 ton of clover hay is somewhat superior to 3 tons of uncut stover. Thirty-four per ct. of the coarse, uncut stover was left uneaten in these trials. Had the material been cut, the cows would have wasted somewhat less and the stover would have then had a higher value per ton. This trial shows the heavy losses incident to feeding dry corn forage, which if ensiled would be wholly consumed. (**300-2**)

623. Timothy hay.—While timothy hay is a standard and most satisfactory roughage for the horse, it is unsatisfactory for the dairy cow. It lacks protein, is not very palatable to cows, and has a constipating effect quite opposite to the beneficial action of legume hay. The value of mixed clover and timothy hay for cows will depend on the proportion of clover present.

To demonstrate the poor results secured when timothy hay is fed with other feeds likewise low in protein, Fraser and Hayden of the Illinois Station[90] conducted a trial on a dairy farm in which 2 lots each of 8 cows were fed by the reversal method for two 42-day periods. The cows were given 12.5 lbs. per head daily of a concentrate mixture of 2.5 parts corn meal and 1 part wheat bran with the roughages shown in the table:

Timothy hay vs. alfalfa hay when fed with protein-poor feeds

	Average roughage allowance	Average daily yield of milk Lbs.
I.	Timothy hay, 10 lbs. Corn stover, 10 lbs.	23.4
II.	Alfalfa hay, 10 lbs. Corn stover, 10 lbs.	27.5

When fed the alfalfa-hay ration, which had a nutritive ratio of 1 : 6.6, the cows produced 17.5 per ct. more milk than on the unbalanced timothy-hay ration, the nutritive ratio of which was 1 : 10.2. The timothy-fed cows lost in weight and were in poor condition generally, a number being "off feed" at times. This trial shows clearly that when timothy hay must be fed it should be supplemented by concentrates high in protein. (**312**)

624. Upland prairie vs. timothy hay.—Haecker of the Minnesota Station[91] compared native upland prairie hay of excellent quality with medium fine, early-cut timothy hay properly cured. Sixteen cows were used during the trial lasting 77 days, the same quantity of grain and hay being supplied in each case. The returns in milk and fat were practically the same from the 2 kinds of hay. This study[92] was repeated with the same results. It is fair, then, to hold that good upland prairie hay, like that of the Minnesota region, is equal to timothy hay with the dairy cow. (**325**)

[90] Ill. Bul. 146. [91] Minn. Bul. 35. [92] Minn. Bul. 67.

625. Bermuda hay.—Lloyd of the Mississippi Station[93] studying the returns from a herd of 30 to 60 cows during 3 years, concludes that Bermuda hay equals timothy hay for milk and butter production. (**320**)

626. Johnson-grass hay.—Moore of the Mississippi Station[94] found Johnson-grass hay nearly as valuable as cowpea hay when corn silage, cottonseed meal, and wheat bran were the other feeds given. Had less rich and palatable concentrates been fed, Johnson-grass hay would probably have shown but half to two-thirds of the value of the cowpea hay. (**321**)

627. Salt-marsh hay.—Lindsey and Jones of the Massachusetts (Hatch) Station,[95] in trials with 12 cows, covering 7 months, found that where 10 lbs. of various kinds of salt-marsh hay were given daily in place of an equal weight of mixed hay, the milk flow was decreased from 2 to 5 per ct. They state: "When fed directly after milking, no objectionable flavor could be detected in the milk or butter. It is possible that if these hays were cut very soon after being covered by the tide they would then produce a disagreeable flavor." (**325**)

628. Cottonseed hulls.—Cottonseed hulls are a roughage fair in carbohydrate content, but very deficient in crude protein, and are rather unpalatable to cows. Moore of the Mississippi Station,[96] in feeding trials with dairy cows, found 100 lbs. of well cleaned cottonseed hulls equal to 67 lbs. of prime Johnson-grass hay. Soule of the Texas Station[97] found cottonseed hulls nearly equal to sorghum hay for cows. Nourse of the Virginia Station[98] considers cottonseed hulls about equal to oat straw in feeding value. Conner of the South Carolina Station[99] found cottonseed hulls decidedly inferior to corn stover, and Michels of the North Carolina Station[100] found stover of rather poor quality equal to the hulls. Flint and Dorman[101] report from trials on Georgia farms that carbohydrates can be supplied under their conditions much more cheaply in the form of corn silage than by cottonseed hulls. Silage also stimulates a greater flow of milk, and is palatable and succulent, aiding in keeping the animals in good condition. Failing to appreciate the value of the forage from the corn plant, southern dairymen often leave the corn stalks standing in the field and purchase cottonseed hulls for roughage. (**251**)

V. Succulent Feeds

629. Corn silage.—Succulent feeds are of even more importance in the feeding of the dairy cow than of the other farm animals. On account of their cooling, slightly laxative action, such feeds aid greatly in keeping the digestive tract of this hard-working animal in good condition, as well as whetting the appetite so that large amounts of feed are consumed. Thruout the chief dairy sections of the United States corn

[93] Miss. Bul. 70.
[94] Miss. Rpt. 1895.
[95] Mass. (Hatch) Bul. 50.
[96] Miss. Rpt. 1903.
[97] Tex. Bul. 47.
[98] Va. Bul. 148.
[99] S. C. Bul. 66.
[100] N. C. Bul. 199.
[101] Ga. Bul. 80.

silage furnishes the cheapest form of succulence. Due largely to the fact that the silage made during earlier years was frequently of poor quality and fed in a careless manner, a widespread belief existed that silage injured the flavor of the milk. For many years the largest milk condensing company in the country prohibited the use of silage by its patrons. Experience has now abundantly demonstrated that when good silage is fed under proper conditions the quality of the milk is thereby improved, rather than impaired. Like other feeds, silage may be abused. Only that which is well made should be used, and this should be fed after milking and be eaten up clean at each feed, none being left scattered on the floor of the stable, the air of which should be kept pure and wholesome by proper ventilation. If such conditions prevail, no one need fear ill effects from feeding silage to dairy cows, for when thus fed even the milk condensing factories no longer object to its use. The daily allowance of silage commonly fed ranges from 20 to 40 lbs. per 1,000 lbs. live weight. A common rule is to feed 3 lbs. of silage and 1 lb. of dry roughage per 100 lbs. live weight. (**300-5**)

630. Corn silage vs. fodder corn.—Tests of corn silage and field-cured fodder corn at the Vermont[102] and Wisconsin[103] Stations were conducted in the following manner: Two rows of maturing corn extending across the field were placed in shocks, while the next 2 rows were run thru the feed cutter and placed in the silo. By thus alternating until the silo was filled, substantially equal quantities of material having the same composition were obtained as silage and shock corn, respectively. The field-cured fodder, after being run thru the cutter, was fed in opposition to the silage to dairy cows along with equal quantities of hay and grain.

At the Vermont Station the green fodder corn, converted into silage and fed with hay and grain, produced 11 per ct. more milk than the same amount of green corn dried and fed with the same allowance of hay and grain. In the Wisconsin trial the corn crop produced 243 lbs., or 3 per ct., more milk per acre when fed as silage than when fed as dried corn fodder.

In the following table are summarized the results of these and other trials in which the amount of milk produced from 100 lbs. of total dry matter in rations containing silage or corn fodder was determined:

Corn silage vs. fodder corn for milk production

Station and number of trials	Milk from 100 lbs. dry matter	
	Silage ration Lbs.	Fodder ration Lbs.
Wisconsin (Rpt. 1888), 3 trials	104.2	95.8
Wisconsin (Rpt. 1889), 3 trials	110.5	104.8
Vermont (Rpt. 1892), 1 trial	82.0	76.5
Pennsylvania (Rpt. 1890), 1 trial	111.9	106.3
New Jersey (Bul. 122), 1 trial	116.2	103.0
Average of 9 trials	106.0	98.6

[102] Vt. Rpt. 1891. [103] Wis. Rpt. 1891.

Averaging these trials we find that 7.4 lbs. more milk was produced from 100 lbs. of dry matter in the silage rations than in the rations containing fodder corn. The higher value of the silage is not due to any increased digestibility of the silage over well-cured dry fodder, for we have seen that ensiling tends to decrease the digestibility of forage rather than to increase it. (**83**) The superiority of silage must be largely due to the fact that while good-quality silage is eaten with little or no waste, a considerable part of the corn fodder is usually left uneaten. Various trials show that the dry matter of that part of the corn fodder which is actually consumed may have just as high a nutritive value as an equal weight of dry matter in corn silage.[104] Another reason why silage gives better results than dry corn fodder is that cows fed the succulent, palatable silage usually consume a heavier ration than those fed the dry fodder and hence have a larger amount of nutrients available for milk production after the maintenance requirements of the body have been met.

631. Corn silage vs. hay.—To determine the relative value of corn silage and mixed hay (mostly timothy) Jordan fed 4 cows at the Maine Station[105] for three 14-day periods. During the first period the cows were fed good hay; during the second, hay and silage; and during the last, hay again, the same amount of concentrates being fed thruout the trial. When the cows were changed from good hay to both silage and hay their milk flow increased 7 per ct. and when changed back it decreased 8 per ct. The silage fed in this trial was watery and contained but 16.7 per ct. dry matter, while average silage from well-matured corn contains about 26 per ct. dry matter. Jordan found 444 lbs. of this silage, which had less than two-thirds the value of high-quality silage, slightly superior in feeding value to 100 lbs. of the hay fed. It is fair to conclude that had the silage been of average quality 280 lbs. would have been slightly superior to 100 lbs. of hay.

In an extended trial with 6 cows Hills of the Vermont Station[106] found that when 3.5 lbs. of corn silage was substituted for 1 lb. of mixed timothy, red top, and clover hay, the milk yield was increased 7 per ct. Rating hay at $10 and silage at $3 per ton, there was a gain of 1.66 cents daily per cow by replacing one-third of the hay with silage. From these data we may conclude that for dairy cows 280 to 350 lbs. of good corn silage is worth rather more than 100 lbs. of mixed hay. In the feed unit system as revised by Woll[107] and in the Armsby table of energy values corn silage is rated at half the value of timothy hay. (**171, 178**)

To determine the relative value of corn silage and alfalfa hay Carroll of the Utah Station[108] fed 2 lots of 7 cows each the rations shown in the table for 2 alternate 28-day periods. The concentrate allowance consisted of a mixture of equal parts wheat bran and rolled barley.

[104] Wis. Rpts. 1890, 1891.
[105] Me. Rpt. 1889.
[106] Vt. Rpt. 1901.
[107] Wis. Cir. 37.
[108] Information to the authors.

Relative value of corn silage and alfalfa hay

Average ration		Average daily yield Milk Lbs.	Fat Lbs.
Ration I			
Alfalfa hay, 22.2 lbs.			
Corn silage, 21.3 lbs.	Concentrates, 4.1 lbs............	27.2	0.99
Ration II			
Alfalfa hay, 29.0 lbs.	Concentrates, 4.0 lbs............	26.6	0.95

When fed silage the cows yielded 2 per ct. more milk and 4 per ct. more fat, but were given 2.5 per ct. more grain. We may therefore conclude that 6.8 lbs. of alfalfa hay was fully replaced by 21.5 lbs. of corn silage, or 100 lbs. of hay by 310 to 320 lbs. of silage.

632. Silage from the sorghums.—Next in value to corn silage is that from the grain and the sweet sorghums. Reed and Fitch found kafir silage practically equal to corn silage when fed with hay and grain in a trial at the Kansas Station.[109] In each of 2 trials the cows produced 3 per ct. more milk and 1 per ct. more fat when fed corn silage than when fed silage from sweet sorghum, showing this silage to be but little inferior to that from the corn plant. (**309**)

633. Silage from the legumes.—Tho there is far less certainty of securing silage of good quality from clover or alfalfa than from corn and the sorghums, these legumes are sometimes ensiled, especially when the weather does not permit making them into satisfactory hay. (**342, 348**) In each of 3 years Clark ensiled red clover at the Montana Station[110] and fed the silage to dairy cows in comparison with clover hay. When from 32 to 43 lbs. of clover silage was fed per head daily with clover and timothy hay and concentrates, 233 lbs. of the silage proved equal to 100 lbs. of good clover hay. On the silage ration the yield of milk was increased 5.7 per ct. and of fat 4.3 per ct. Clark reports that the cows relished the silage during the winter months, but that in summer it became darker in color and acquired a strong odor, a point also observed by Reed at the Kansas Station[111] with alfalfa silage. Such combinations as field peas with oats, soybeans or cowpeas with corn or the sorghums, and vetch with oats, wheat, or barley, make satisfactory silage. (**357-9**)

634. Mixed silage vs. heavy concentrates.—At the Ohio Station[112] Williams fed 2 uniform lots of 4 cows each the rations reported in the table during 4 months to determine whether a large part of the concentrates usually supplied could not be replaced by silage composed of 2 parts soybeans, 1 part cowpeas, and 7.5 parts of rather watery corn silage. The 2 rations contained practically the same amount of dry matter and crude protein.

[109] Kan. Cir. 28.
[110] Mont. Bul. 94.
[111] Hoard's Dairyman, 47, 1914, p. 889.
[112] Ohio Bul. 155.

Feeding mixed silage in place of part of the concentrates

Average ration		Average daily yield Milk Lbs.	Fat Lbs.
Lot I			
Mixed silage, 58.0 lbs.	Oil meal, 2.0 lbs.		
Mixed hay, 6.8 lbs.	Bran, 2.0 lbs.	19.6	1.03
Lot II			
Stover, 4.7 lbs.	Oil meal, 2.5 lbs.		
Mixed hay, 6.5 lbs.	Corn meal, 5.0 lbs.		
	Bran, 6.0 lbs.	16.9	0.80

It is seen that the cows fed 58 lbs. of mixed silage with 4 lbs. of concentrates yielded more milk and fat than those receiving 13.5 lbs. of rich, expensive concentrates and no silage. Less dry matter was consumed by the silage-fed cows for 1 lb. of fat than by those getting no silage. During the trial the fat yield of the silage-fed cows increased 1.9 per ct., while that of the others shrank 14.2 per ct. These results forcibly illustrate how protein-rich silage may aid the dairyman in reducing the cost of producing milk.

635. Apple-pomace silage.—Hills[113] fed cows daily allowances of 24 to 35 lbs. of apple-pomace silage, as much as they would eat in addition to 8 lbs. of grain and 10 to 12 lbs. of hay. On apple-pomace silage the cows consumed somewhat more dry matter than those getting corn silage, with a corresponding increase in milk flow. The apple-pomace silage had no deleterious influence on the cows or their milk. (**384**)

636. Other silage studies.—Hills of the Vermont Station[114] found that rye silage was drier and less readily eaten than corn silage, and made 10 per ct. less milk and butter. Cows changed from corn to rye silage shrank 20 per ct. in milk, while on changing back from rye to corn they gained 2 per ct. Good corn silage gives better results than good Hungarian-grass hay or silage. (**318**)

637. Roots.—Since roots may be regarded as watery concentrates rather than roughages (**22, 365**) the question naturally arises as to their value in replacing the concentrates in the ration. In studying this problem Friis of the Copenhagen (Denmark) Station[115] conducted extensive trials on different farms in which cows were fed the same basal ration, consisting of 6.5 lbs. of hay and 10 lbs. of straw, and were given in addition varying amounts of cereal grains, cottonseed meal, and mangels or other roots. Friis concluded that 1 lb. of dry matter in roots is equal in feeding value to 1 lb. of Indian corn or of a mixture of barley, oats, and rye, or to 0.75 lb. of cottonseed meal.

In trials during 2 years Wing and Savage of the New York (Cornell) Station[116] found that 1 lb. of dry matter in mangels is equal to 1 lb. of dry matter in grain, and that mangels can successfully replace half the grain ordinarily fed in a ration of grain, mixed hay, and silage. The

[113] Vt. Rpt. 1903.
[114] Vt. Rpt. 1907.
[115] Expt. Sta. Rec. 14, 1903, p. 801; Landökon. Forsög (Copenhagen), 1902, p. 30.
[116] N. Y. (Cornell) Bul. 268.

Cornell studies led to the conclusion that with concentrates costing $30 per ton mangels are an economical feed for dairy cows when they can be produced and stored for $4 per ton,—a high figure for this comparatively easily-grown crop. (**368**)

Haecker of the Minnesota Station[117] has likewise found that 1 lb. of dry matter in mangels or rutabagas is substantially equal to 1 lb. of mixed grain, 11 lbs. of mangels or 9 lbs. of rutabagas having the same value as 1 lb. of grain.

In the earlier years it was thought that the feeding of roots produced watery milk, but the extensive experiments in Denmark and this country with roots and silage prove beyond a doubt that the milk of the cow cannot be watered by supplying succulent feeds.

638. Dry matter in roots and silage.—The value of the dry matter in roots and corn silage for milk production has been studied at the Ohio,[118] Pennsylvania,[119] and Vermont[120] stations with the following results:

Milk from 100 lbs. of dry matter in corn silage and beet rations

Station	Beet ration Lbs.	Silage ration Lbs.
Ohio Station, 1889	59	62
Ohio Station, 1890	59	60
Ohio Station, 1891	62	66
Ohio Station, 1892	69	76
Pennsylvania Station	87	82
Vermont Station	113	119

It will be seen that, altho practically all of the dry matter in beets is digestible and only a part of that in corn silage, in each of these trials dairy cows gave somewhat better returns on the dry matter of corn silage than on that in the beet ration. On the other hand, Wing and Savage at the Cornell Station[121] found 1 lb. of dry matter in mangels slightly superior to 1 lb. of dry matter in corn silage. (**365–74**)

639. Sugar beets vs. corn silage.—Haecker of the Nebraska Station[122] compared corn silage and sugar beets with 2 lots of 5 cows each, fed for a period of 5 weeks. The cows were given 6 to 10 lbs. per head daily of a mixture of equal parts of oats, corn, and wheat bran, with hay and succulence as shown in the table:

Corn silage compared with sugar beets

	Allowance of hay and succulence		Average daily yield Milk Lbs.	Fat Lbs.
I.	Corn silage, 30 lbs.	Alfalfa hay, 10 lbs.	17.4	0.84
II.	Sugar beets, 30 lbs.	Alfalfa hay, 10 lbs.	16.1	0.78

It is shown that where 30 lbs. of corn silage was fed against an equal weight of sugar beets, the small difference in yield of milk and fat was in

[117] Minn. Rpt. 1913.
[118] Ohio Rpt. 1893.
[119] Penn. Rpt. 1890.
[120] Vt. Rpt. 1895.
[121] N. Y. (Cornell) Bul. 268.
[122] Nebr. Bul. 76.

favor of the silage, as might be expected from the fact that corn silage contains considerably more dry matter than sugar beets.

640. Addition of roots to ration containing silage.—To determine whether the addition of roots to an already excellent ration of corn silage, clover hay, and concentrates would increase the yield of milk or fat by dairy cows, Shaw and Norton carried on trials during 3 years at the Michigan Station[123] with a total of 40 cows. Each year 2 lots were fed the rations shown in the table by the reversal method for periods averaging 26 days in length:

Effect of roots when added to ration containing silage

Average ration	Average daily yield		Average feed cost of*	
	Milk	Fat	100 lbs. milk	1 lb. fat
	Lbs.	Lbs.	Cents	Cents
Ration I				
Roots, 18.3 lbs.				
Corn silage, 30.6 lbs.				
Clover hay, 5.0 lbs.				
Concentrates, 9.2 lbs.	23.8	0.93	66.5	17.0
Ration II				
Corn silage, 30.8 lbs.				
Clover hay, 5.0 lbs.				
Concentrates, 9.2 lbs.	22.5	0.88	62.3	15.8

*Cost of feeds per ton: concentrate mixture, $17.60 to $19.21; clover hay, $5.00; corn silage, $2.50; and roots, $2.00.

On Ration I, which was practically the same as Ration II with the exception that it contained in addition 18.3 lbs. of roots, the average daily yield of milk was increased 1.3 lbs. and of fat 0.05 lb. This gain was not enough to offset the cost of the roots fed, for the average cost of 100 lbs. milk was 4.2 cents and of 1 lb. of fat 1.2 cents lower on the ration containing no roots. While breeders feeding cows heavily on official test may find it advisable to feed roots in addition to a liberal allowance of corn silage for the sake of the small increase in yield, this practice will rarely be economical for dairymen in general. **(365)**

641. Potatoes.—A heavy allowance of potatoes produces milk and butter of poor flavor. According to Pott[124] cows of average weight should not be fed more than 33 lbs. per head daily of cooked potatoes and somewhat less of the raw tubers. When feeding a heavy allowance of potatoes Hills of the Vermont Station[125] found the dry matter in corn silage superior to that in raw potatoes. The cows ate the potatoes readily, but at 15 cents a bushel they were more costly than corn silage. Butter from the potato-fed cows was salvy. **(374)**

642. Soilage.—During 3 summers Woll, Humphrey, and Oosterhuis at the Wisconsin Station[126] fed 1 lot of cows which had access to limited pasture a succession of soiling crops in addition to a small allowance of

[123] Mich. Bul. 240.
[124] Handb. Ernähr. u. Futter., II, 1907, pp. 363–364.
[125] Vt. Rpt. 1896.
[126] Wis. Bul. 235.

mixed concentrates. Another lot, otherwise fed similarly, received corn silage instead of soilage. In 2 of the trials each lot was given a small allowance of hay. The results of the trials, which averaged 82 days, are given in the following table:

Soilage vs. silage as supplements to pasture

	Average ration	Average daily yield Milk Lbs.	Fat Lbs.
Lot I			
Soilage, 28.1 lbs.			
Mixed hay, 2.2 lbs.			
Pasture, limited	Concentrates, 5.4 lbs.	23.9	0.92
Lot II			
Corn silage, 27.3 lbs.			
Mixed hay, 2.0 lbs.			
Pasture, limited	Concentrates, 5.4 lbs.	22.5	0.94

The cows fed soilage, consisting of red clover, peas and oats, sweet corn, field corn, and "succotash" (mixed oats, peas, and corn), yielded no more milk and slightly less fat than those fed corn silage. Silage was relished rather better than the succession of soiling crops. In a similar trial by Frandsen at the Nebraska Station[127] the feed cost per pound of butter fat was 24.5 cents with soiling crops and 21.5 cents when corn silage was used. Since soilage is far more expensive and much more inconvenient to feed than silage (**418–20**), the latter is preferred by dairymen as a supplement to pasture, except where too few cows are kept to consume the silage fast enough to prevent its spoiling. When silage is not available for summer feeding, the wise dairyman will provide a well-planned succession of soiling crops to maintain the milk flow when pastures are scant, knowing that it is well-nigh impossible to bring the yield of milk back to near the former amount if it has once been checked by insufficient feed. (**421–2**)

643. Wet beet pulp.—Wing and Anderson of the New York (Cornell) Station[128] found that cows will eat 50 to 100 lbs. of fresh beet pulp per day in addition to 8 lbs. of grain and 6 to 12 lbs. of hay. The dry matter in wet beet pulp proved equal to that in corn silage. As the pulp comes from the factory it contains about 10 per ct. dry matter, or about one-third as much as does corn silage of good quality. Beet pulp may have a higher value than given above when no other succulent food is supplied. The fermented pulp appears to be more palatable and satisfactory, tho even fresh pulp seems to stimulate the consumption of dry roughage. There are occasional reports of beet pulp tainting the milk. Buffum and Griffith of the Colorado Station[129] found 2 lbs. of fresh beet pulp equal to 1 lb. of sugar beets for dairy cows. (**274**)

[127] Hoard's Dairyman, 47, 1914, p. 403. [129] Colo. Bul. 73.
[128] N. Y. (Cornell) Bul. 183.

CHAPTER XXIII

RECORDS OF PRODUCTION OF DAIRY COWS—FEED REQUIRED BY COW AND COST OF PRODUCING MILK AND FAT

I. Records of Production of Dairy Cows

That successful dairying depends primarily on the selection of individual cows of good productive capacity has already been pointed out. (**544-7**) It is therefore important to consider the various agencies which have been of service in pointing out to dairymen the profitable and the unprofitable animals in their herds, and in enabling them more intelligently to feed and breed for production. Chief among these agencies are the cow-testing associations, the system of official testing, the advanced registers, dairy cow censuses, and public competitions.

644. Cow-testing associations.—The remarkable development of dairying in northern Europe during the past 20 years has been due in large part to the work of the cow-testing associations. From 1895, when the first association was organized in Denmark with 13 herds entered, the growth has been most rapid, until in 1914 there were between 2,500 and 3,000 such associations in European countries. In these organizations a trained tester is employed, who spends a day every month with each of the herds in the association. Arriving on the farm in the afternoon he weighs and samples the milk from each cow at milking time. He furthermore weighs the concentrates given each cow and also the roughage which several cows get and then estimates the approximate amount given to each cow in the herd. The following morning this is repeated, after which the samples of milk are tested for butter fat. From this day's record he computes the milk and fat production and cost of feed for each cow for the current month. While such records are not as exact as if every milking were weighed, careful studies show the results to be within 2 per ct. of the actual production of the cow. The tester not only makes these records, but he also studies the local feed market and aids the dairymen in working out the most economical rations for their herds. Many dairymen who would not go to the trouble of testing their herds themselves are glad to secure this service at small expense as a member of the association.

The improvement wrought by these associations is marvelous. In Denmark, largely due to their work, the average annual yield of butter per cow has increased from 112 lbs. in 1884 to 224 lbs. in 1908. In 10 years one association in Sweden increased the annual production of butter fat 109 lbs. per cow.[1]

[1] Carroll, Utah Bul. 127.

645. Cow-testing associations in the United States.[2]—While the cow-testing associations are yet in their infancy in this country, they have already accomplished much good. In 1914 the total number grew from 100 to 163, or 63 per ct. The first association in the United States was organized in Newaygo County, Michigan, in 1905, in charge of Helmer Rabild, now of the United States Department of Agriculture. The following table shows the improvement brought about in 8 years in 7 herds which have been in this association since its organization:

Improvement in 7 herds in Newaygo cow-testing association

Year	No. of cows	Average yield of milk	Fat content of milk	Annual yield of fat	Value of fat	Annual cost of feed	Returns over cost of feed
		Lbs.	Per ct.	Lbs.	Dollars	Dollars	Dollars
1906	50	5885.0	3.92	231.1	53.88	31.65	22.23
1907	60	5952.7	3.94	234.6	68.23	39.79	28.44
1908	69	6095.4	4.15	253.3	69.20	40.45	28.75
1909	72	6302.6	4.28	269.7	83.98	42.05	41.93
1910	79	6208.8	4.28	265.7	90.22	49.52	40.70
1911	80	6411.0	4.38	280.9	80.65	48.48	32.17
1912	80	6154.8	4.45	273.9	95.73	44.46	51.27
1913	69	6123.4	4.64	284.7	100.35	49.27	51.08

These herds were much above the average for the whole country when the association was organized, averaging 231 lbs. of butter fat per cow, while the estimated average annual production for the United States is but 160 lbs. During the 8 years of record the average annual yield of butter fat was increased nearly 54 lbs. or 23 per ct. over that for 1906. Tho the prices of feeds have advanced markedly, the net returns over cost of feed have more than doubled in these herds.

646. Official tests and advanced registry of dairy cows.—The establishment by the dairy breed associations of advanced registers for pure-bred cows is another important movement in the development of the dairy industry. Cows are entitled to place in these registers of production only when their yield in tests conducted by representatives of the state experiment stations or of the breed associations has reached the standard set by the association. Entry in these registers increases the money value, not only of the given cow, but also of her relatives, for progressive breeders in their selection of animals now rely more and more upon records of production and less upon show-ring successes.

647. Keeping records on the farm.—For the dairyman who desires to keep his own records of the production of his cows, the following, condensed from Eckles,[3] will be helpful: The only records which are entirely satisfactory are those setting forth the daily production of each individual cow. This does not require as much work as one would anticipate, if a convenient spring balance and handy milk sheets for entry of the records are provided. Daily individual records make possible the feeding of each cow with the greatest economy, enable the herds-

[2] From circular issued by U. S. Dept. Agr.

[3] Dairy Cattle and Milk Production, pp. 136-140.

man to detect sickness quickly by the decline in milk flow, and aid in judging the efficiency of the different milkers. Where the weight of each milking is recorded, it is sufficient to take a sample covering 3 to 5 days of each month for the butterfat determination.

Those who feel that they cannot spend the time necessary to weigh each milking may obtain reasonably satisfactory records by weighing and sampling the milk of each cow regularly on 3 consecutive days each month thruout the year. The average yield of milk and fat for this period is taken as the average for the month. Another method of less value, but better than no testing, is to record the production of each cow for 7 consecutive days at intervals of 3 months.

648. Unreliability of short tests.—Glover[4] reports that during 3 years the best weekly record of one cow in an Illinois dairyman's herd was 309 lbs. of milk and 10.5 lbs. of fat. In her best lactation period, which lasted 266 days, she produced 5,355 lbs. of milk and 184 lbs. of fat. The best weekly record of another cow was 197 lbs. of milk and 10.2 lbs. of fat, less than the first cow. During her best lactation period (315 days) this cow, however, yielded 7,190 lbs. of milk and 367 lbs. of fat. This well shows the unreliability of short tests. Time, the scales, the Babcock fat test, combined with good judgment, are all essential in determining the true value of dairy cows.

649. A herd record.—On taking charge of the New York (Cornell) Station[5] Roberts found a herd of cows yielding about 3,000 lbs. of milk per head yearly. After years of careful breeding and selection the records shown in the table below were actually made:

One year's milk and fat record with a herd of 20 cows

No. of cow	Age		Cost of feed	Milk produced	Feed cost of 100 lbs. milk	Fat produced	Feed cost of 1 lb. of fat
	Yrs.	Mo.	Dollars	Lbs.	Dollars	Lbs.	Cents
No. 1....	7+		44.24	8,029	0.55	391.6	11.5
No. 2....	5	4	47.65	9,740	0.49	309.2	15.5
No. 3....	3	5	42.00	4,743	0.89	233.6	18.0
No. 4....	1	9	49.07	6,009	0.82	219.3	22.5
No. 5....	7+		38.74	6,215	0.62	326.7	12.0
No. 6....	1	10	41.24	2,830	1.48	159.0	26.0
No. 7....	6	4	52.06	11,165	0.47	418.0	12.5
No. 8....	4		39.96	5,671	0.70	285.1	14.0
No. 9....	3		36.24	3,388	1.07	197.3	18.5
No. 10....	4	8	46.51	6,324	0.74	224.7	21.0
No. 11....	1	9	43.80	5,136	0.85	160.8	27.0
No. 12....	3	5	43.66	5,786	0.75	294.3	15.0
No. 13....	10	4	44.34	5,459	0.81	195.3	22.5
No. 14....	2	4	45.98	7,757	0.59	260.3	17.5
No. 15....	3	4	47.44	9,003	0.53	299.1	16.0
No. 16....	6	4	43.12	9,777	0.44	330.6	18.0
No. 17....	7	3	47.87	10,417	0.46	302.9	16.0
No. 18....	3	4	48.63	7,955	0.61	282.4	17.0
No. 19....	7+		53.38	8,656	0.62	382.8	14.0
No. 20....	7+		49.08	10,754	0.46	439.4	11.0

[4] Ill. Cir. 84.

[5] N. Y. (Cornell) Bul. 52.

We observe a considerable range in the cost of feed for the several cows, a wide one in the yield of milk, and a marked difference in the cost of producing milk and fat. While in 1875 the average milk yield of the cows in the herd was only 3,000 lbs., in 1892 the descendants of the same cows averaged more than 7,000 lbs. This table teaches that even with good, well-fed herds it is of the highest importance to study the feed consumption and milk and fat production of each individual, in order that only the best cows and their progeny may be retained.

650. Dairy cow censuses.—Many years ago Hoard's Dairyman, thru trained representatives, began studying the returns from cows on dairy farms in many states and under varying conditions. Following the first "cow census," conducted under the supervision of W. D. Hoard in 1887, a series of 26 canvasses were taken from 1899 to 1908, including 2,163 herds which contained 28,447 cows. In the following table are summarized some of the most important data compiled in these extensive surveys:[6]

Summary of the Hoard's Dairyman cow censuses

	No. of cows	Annual yield of butter fat	Cost of feed	Gross returns	Returns over cost of feed	Received for $1 worth of feed	Feed cost of butter fat per lb.
		Lbs.	Dols.	Dols.	Dols.	Dols.	Cts.
Type of cow							
Good dairy type	9,365	189.0	33.95	51.33	17.38	1.51	18.5
Lacking dairy type	8,104	138.2	32.01	34.04	2.03	1.06	23.0
Value of silage							
Herds fed silage	6,689	181.8	34.98	48.48	13.50	1.39	18.9
Not known to be silage-fed	21,759	151.2	32.95	39.41	6.46	1.20	22.2
Value of good stables							
Herds in good stables	9,506	180.0	34.53	48.65	14.12	1.41	18.7
Herds in poor stables	3,775	130.0	32.53	32.76	0.23	1.01	26.6
Value of dairy literature							
Owners read dairy papers	6,202	185.0	34.78	49.32	14.54	1.42	17.5
Owners read no dairy papers	9,122	136.7	35.00	36.85	1.85	1.05	28.8
Good and poor producers							
Most profitable herds	3,848	234.0	33.66	59.84	26.18	1.78	14.5
Least profitable herds	3,459	102.2	33.76	40.46	−6.70	0.80	32.1

The various differences recorded are not wholly due to the different single factors. For example, the low results from the herds in poor stables were not due to this alone but also to the fact that, compared with the cows in good stables, a greater proportion of these cows were undoubtedly lacking in dairy type and that a smaller number were fed silage or belonged to progressive owners who read dairy literature and applied its teachings in their business. The poor dairyman is usually deficient in not one but in many particulars. While the herds in which the cows were of good dairy type returned $17.38 per cow on the average

[6] Compiled in U. S. Dept. Agr., Bur. of Anim. Indus., Bul. 164.

over cost of feed, the herds lacking in dairy type little more than paid for the feed they ate. The cows fed silage yielded $1.39 for each dollar's worth of feed consumed, while those not known to have been fed silage returned but $1.20. Dairymen who read dairy papers secured a profit over cost of feed of $14.54 per cow, while those not directly influenced by dairy literature received only $1.85 per cow.

651. Exposition breed tests.—Tests of pure-bred cows of various breeds for the production of milk and butter fat were conducted at the World's Columbian Exposition held in Chicago in 1893; at the Pan-American Exposition held in Buffalo in 1901; and at the Louisiana-Purchase Exposition held in St. Louis in 1904. In each case the test was supervised by a joint committee composed of delegates representing, on the one hand, the various breed associations interested, and on the other the Association of American Agricultural Colleges and Experiment Stations. The representatives of the several breed associations had direct and full charge of the cows and their feed and care in all particulars. The representatives of the colleges and stations took charge of all weighings of feed as well as of milk and conducted all analyses of the milk.

From the vast accumulation of data gathered during these tests the following condensed table is compiled, giving some of the more striking and helpful findings. The data for the Columbian Exposition test are taken from the *Jersey Bulletin*, 1893, and the *Journal of the British Dairy Farmers' Association*, 1894; for the Pan-American test, from the *Holstein-Friesian Register*, October, 1901; and for the Louisiana-Purchase Exposition, from the *Dairy Cow Demonstration* of the Louisiana-Purchase Exposition, Farrington, published by *Hoard's Dairyman*.

In these competitive tests the cows were selected and entered by the several breed associations, there being no restrictions as to choice. The chosen specimens of each breed were managed as to feed, water, and care entirely in accordance with the ideas and wishes of the committee in charge of that particular breed. The feeding and milking of each cow, however, was done in the presence of representatives of the colleges and experiment stations. A price was established for each and all kinds of feed by the joint committee. The sub-committee in charge of each competing herd was allowed to give as much of any and all kinds of the various feeds as it wished to each cow under its care. Full records were kept of everything eaten, of all the milk yielded, the gain or loss in the weight of the cows, etc. A price was established for milk and fat so that the returns of each cow over the cost of the feed consumed could be credited. The table which follows shows the results of one test at each exposition condensed and arranged for comparative study.

Since widely different prices were charged for feed and allowed for products at the different expositions, the returns from milk and fat over cost of feed in the different tests should not be compared with one another.

Summary of principal tests of pure-bred dairy cows at the Columbian, Pan-American, and Louisiana-Purchase Expositions

Breed	Av. daily yield per cow			Per cent fat	Feed cost 100 lbs. milk	Feed cost 1 lb. fat	Gain in live wt.	Daily return over feed cost
	Milk	Fat	Total solids					
Columbian Exposition, Chicago, 1893: best cow in 90-day test								
	Lbs.	Lbs.	Lbs.		Cents	Cents	Lbs.	Cents
Jersey	40.4	2.0	...	4.9	70.2	14.3	81	81.3
Guernsey	39.0	1.7	...	4.4	64.6	14.8	−13	64.2
Shorthorn	40.9	1.5	...	3.7	65.5	18.0	115	58.5
Pan-American Exposition, Buffalo, 1901: average of 5 cows, 146 days								
Jersey	31.0	1.3	4.2	4.2	48.8	11.5	...	22.5
Guernsey	31.6	1.4	4.2	4.3	47.9	11.1	...	23.1
Ayrshire	37.6	1.2	4.6	3.1	40.5	12.9	...	26.4
Shorthorn	36.7	1.2	4.4	3.3	48.4	14.6	...	22.7
Holstein-Friesian	44.2	1.3	5.1	3.0	40.2	13.2	...	28.6
Polled Jersey	23.4	1.0	3.1	4.4	51.5	11.6	...	15.7
French Canadian	28.5	1.1	3.6	3.8	44.2	11.8	...	20.2
Brown Swiss	35.8	1.2	3.5	3.4	45.7	13.4	...	23.3
Red Poll	33.3	1.3	4.2	3.8	45.8	12.1	...	21.8
Dutch Belted	28.0	0.9	3.3	3.2	51.4	16.1	...	15.7
Louisiana-Purchase Exposition, St. Louis, 1904: best and poorest cow, 120 days								
Jersey								
Best cow	48.4	2.3	6.7	4.8	55.0	9.7	77	42.1
Poorest cow	38.8	1.6	5.1	4.1	65.0	13.2	85	22.3
Holstein-Friesian								
Best cow	67.5	2.4	7.5	3.5	45.0	11.0	54	38.4
Poorest cow	47.1	1.5	5.1	3.2	61.0	16.5	147	15.0
Brown Swiss								
Best cow	51.0	1.8	6.1	3.4	54.5	13.7	74	23.1
Poorest cow	38.5	1.5	5.1	3.8	69.5	15.5	147	16.5
Shorthorn								
Best cow	43.4	1.7	5.5	4.0	54.5	11.7	139	27.1
Poorest cow	21.4	0.8	2.7	3.9	107.5	23.5	234	1.6

652. Wisconsin Dairy Cow Competition.—The most extensive breed competition which has been conducted in this country is the Wisconsin Dairy Cow Competition, carried on under the supervision of the Wisconsin Station.[7] Some of the data secured in this contest, in which yearly records were secured for 395 cows, is condensed in the table:

Results of Wisconsin Dairy Cow Competition

	No. of cows	Yearly yield of milk	Yearly yield of fat	Value of products*	Cost of feed	Net returns over cost of feed	Value of products per 100 feed units*
		Lbs.	Lbs.	Dols.	Dols.	Dols.	Dols.
Breed test							
Holstein	158	14,689	503	164.40	91.07	73.33	2.08
Guernsey	157	8,465	421	131.59	70.95	60.64	2.05
Jersey	80	7,047	363	113.00	53.88	59.12	2.05
All breeds							
Highest producers	134	.....	528.8	166.82	79.10	87.72	2.33
Medium producers	133	.....	420.6	133.75	71.08	62.67	2.04
Lowest producers	131	.....	338.9	108.12	65.95	42.17	1.77

* Butter fat, $0.28 per lb., skim milk, $0.20 per 100 lbs.

[7] Wis. Res. Bul. 26; Bul. 226.

The results of this competition show plainly the fact, already emphasized, that high producers yield sufficient product to much more than pay for the larger amount of feed they eat, compared with low-producing individuals. (**544-7**)

653. Forced feeding of cows on test.—The feeding of cows being forced to their utmost production is an art concerning which only general suggestions can be made. Skilled feeders employ heavy allowances of rich concentrates mixed in considerable variety, in addition to legume hay, corn silage, and often roots, soilage, or other succulence. By careful attention to all details and by adapting the ration to the peculiarities of the individual cows, the animals are kept from going off feed on their rich rations.

Farrington[8] gives the following to show the actual rations fed on a certain day to cows of the several breeds in the Louisiana-Purchase Exposition dairy contest.

Rations fed on the same day at the Louisiana-Purchase Exposition

	Brown Swiss	Holstein-Friesian	Jersey	Shorthorn
Roughage	Lbs.	Lbs.	Lbs.	Lbs.
Long alfalfa hay	7	..	18.0	9
Cut alfalfa hay	..	15	6.0	..
Corn silage	..	..	16.0	24
Green cut corn forage	40	15	....	..
Green cowpeas	..	35	....	..
Total roughage (green and dry)	47	65	40.0	33
Concentrates				
Wheat bran	..	2	3.0	4
Linseed oil meal	..	..	2.0	2
Ground oats	..	..	2.5	2
Hominy feed	8	5	2.5	3
Gluten feed	..	..	5.0	2
Corn meal	..	..	1.5	..
Corn hearts	..	..	2.5	2
Cottonseed meal	1	1	....	2
Distillers' grains	15	14	....	4
Total concentrates	24	22	19.0	21

While the roughage supply for the cows under test was not large, a heavy concentrate allowance of from 19 to 24 lbs. was fed daily, the Brown Swiss cows getting the largest and the Jerseys the least. Haecker of the Minnesota Station,[9] on studying the records secured in this contest, finds that on such heavy rations the cows converted a smaller percentage of the nutrients into milk than do good cows on ordinary, well-balanced rations. In forced feeding especial care must be exercised lest the health of the cow be permanently injured.

654. Records of great cows.—The following summary of the records of production and feed for champion cows of the leading dairy breeds will be of interest in showing how such great cows have been fed while

[8] Dairy Cow Demonstration, La.-Purch. Expo.

[9] Minn. Bul. 106.

[10] Hoard's Dairyman, 46, p. 477.

on test: Auchenbrain Brown Kate 4th,[10] a pure-bred Ayrshire, yielded 23,022 lbs. of 3.99 per ct. milk, containing 917.6 lbs. fat, in the year ending October 2, 1913. Thruout the test she was milked 3 times a day. During the year she consumed 704 lbs. bran, 762 lbs. hominy, 1,074 lbs. ground oats, 548 lbs. gluten feed, 812 lbs. cottonseed meal, 134 lbs. peanut meal, 908 lbs. linseed meal, 8,000 lbs. silage, 21,000 lbs. beets, and 2,880 lbs. alfalfa hay, the total cost of feed being $184.62. The highest allowance of grain fed was 15 lbs. per day.

During the year ending January 20, 1914, the pure-bred Jersey cow Sophie 19th produced in her fifth lactation period 17,558 lbs. of 5.69 per ct. milk, containing 999.1 lbs. of fat. In this and her preceding 4 lactation periods she yielded a total of 4,428 lbs. of butter, containing 85 per ct. fat,[11] a remarkable record of persistent high production.

Murne Cowan,[12] a 9-yr.-old pure-bred Guernsey, during the year ending February 19, 1915 gave 24,008 lbs. of milk testing 4.57 per ct. fat and containing 1,098.2 lbs. of butter fat. Three months after she completed her record she dropped a vigorous calf. While on test she was milked 4 times daily. During the year she consumed an average of 16.3 lbs. of mixed concentrates daily, and ate in addition 3.5 lbs. dried beet pulp, 1.3 lbs. molasses, 16.0 lbs. of beets, 38.0 lbs. of silage, and 8.5 lbs. of alfalfa hay, with green sweet corn and green alfalfa additional during the summer. The wide variety of feeds often employed by skilled feeders with cows on test is shown by the rations fed this cow during 2 months:

March, 1914. From the 1st to the 18th, 17 lbs. of the following concentrate mixture: bran 4.5 parts; hominy 3.5 parts; ground oats 3 parts; dried distillers' grains and linseed meal, each 2 parts; Sugar Malt and gluten feed, each 1 part. In addition 4.5 lbs. dried beet pulp, 30 lbs. beets, 36 lbs. silage, and 11 lbs. alfalfa hay. From the 19th to the 31st., 19.5 lbs. of the following concentrate mixture: bran 4 parts; hominy, dried distillers' grains, and linseed meal, each 1.5 parts; ground oats and wheat feed, each 3 parts; flaxseed meal 2 parts; Sugar Malt, gluten feed, and peanut meal, each 1 part. In addition 3 lbs. dried beet pulp, 24 lbs. beets, 37 lbs. silage, and 13 lbs. alfalfa hay.

August, 1914. Fourteen lbs. of the following mixture: bran 4 parts; hominy 2.5 parts; ground oats 3.5 parts; dried distillers' grains 5.5 parts; Sugar Malt 2 parts; gluten feed 0.5 part; cottonseed meal and linseed meal, each 1 part. In addition 1.2 lbs. oat feed, 2 lbs. dried beet pulp, 20 lbs. beets, 15 lbs. each sweet corn forage and green alfalfa, 36 lbs. silage, and 9.5 lbs. alfalfa hay.

The total cost of feed for the year was $196.73 and the estimated cost of labor, including feeding, grooming, and milking, $146.

Duchess Skylark Ormsby,[12a] a 5-yr.-old pure bred Holstein cow, yielded 27,761.7 lbs. of milk testing 4.34 per ct. and containing 1205.09 lbs. of butter fat in the year ending November, 1915. She was fed about 22 lbs. daily of a concentrate mixture of wheat bran, oats, brewers' dried grains, gluten feed, distillers' dried grains, hominy feed, and linseed meal. In addition she was given about 24 lbs. of corn silage, 11 lbs. alfalfa hay, and 32 lbs. roots. She was not turned to pasture in summer but was

[11] Hoard's Dairyman, 47, p. 75.

[12] Guernsey Breeder's Jour., 7, 1915, Nos. 3 and 6.

[12a] Holstein-Friesian World, Nov. 13 and Dec. 18, 1915.

given exercise for a half hour daily. At times during the summer oat-and-pea silage and green corn were fed and the roots discontinued.

II. Feed Required by Cow and Cost of Producing Milk and Fat

655. Annual feed requirement.—The next table condenses studies covering from 1 to 6 years at 10 widely separated American stations, showing the yearly feed requirement of cows and their returns in milk and fat.

Annual feed requirement of the dairy cow as found by 10 stations

Stations	No. of years	Feed eaten				Av. cost of feed per cow	Returns	
		Pasture	Concentrates	Soilage, roots, silage	Hay		Milk	Fat
		Days	Lbs.	Lbs.	Lbs.	Dols.	Lbs.	Lbs.
Massachusetts[1]	6	38	2,149	4,938	5,105	90.04	6,036	306
Connecticut[2]	5	152	2,029	8,694	1,830	53.46	5,498	279
New Jersey[3]	6	168*	2,624	16,753	1,825	44.68	6,165	277
Michigan[4]	1	139	2,774	3,638	3,986	35.96	7,009	260
Wisconsin[5]	3	180	1,914	9,448	1,200	37.68	7,061	299
Wisconsin[6]	4	150*	2,010	8,318	1,490	48.82	8,036	344
Minnesota[7]	1	131	3,435	5,306	2,029	37.82	6,408	301
Missouri[8]	1	191	3,027	.....	3,480	35.30	5,927	248
Utah[9]	5	153	1,305	.....	4,518	21.43	5,601	237
Montana[10]	2	150	1,169	.....	6,468	32.45	5,993	250
Nebraska[11]	2	187	1,979	3,692	2,347	31.61	8,783	339

[1] Bul. 145. [2] Bul. 29. [3] Rpts. 1897–1904. [4] Bul. 166. [5] Rpts. 1905–7. [6] Buls. 167, 187, 217. [7] Bul. 35 [8] Bul. 26. [9] Bul. 68. [10] Rpt. 1905. [11] Bul. 101.
* Pasture limited in amount.

At the Massachusetts Station the cows were fed soilage thruout the summer, only the dry cows being turned to pasture. In New Jersey the cows were likewise maintained in summer almost wholly on soilage and silage. At the other stations the pasture period ranged from 131 days in Minnesota to 191 in Missouri. The great value of alfalfa hay in reducing the amount of concentrates fed and the cost of keep is shown by the Utah and Montana reports. The prices of feed have advanced materially since these results were reported so the figures do not represent the present cost of feed per cow. In the second average for Wisconsin, for the years 1907-11, the annual cost of feed per cow is $11.14 higher than the average for the first 3 years reported, 1904-7. Since 1911 the prices have advanced still further. The milk returns varied from 5,498 lbs. per cow in Connecticut to 8,783 lbs. in Nebraska, and the fat from 237 lbs. in Utah to 344 lbs. in Wisconsin.

From this table the intelligent, experienced dairyman can closely estimate the quantity and cost of the concentrates and roughages required to maintain his herd of cows during the year, and the returns in milk and fat he may reasonably expect therefrom.

656. Monthly feed cost of milk.—The following data from 4 widely separated stations, compiled in 1897, show the feed cost of milk and fat for different months of the year at the prices prevailing for feeds and pasture at that date:

Feed cost of 100 lbs. of milk and 1 lb. of fat by months

	New York[1]		Minnesota[2]		Missouri[3]		Utah[4]		Average	
Number of cows	20		23		12		15			
Average weight of cows	1,123 lbs.		976 lbs.		990 lbs.		970 lbs.			
Average fat per cow	286 lbs.		301 lbs.		248 lbs.		222 lbs.			
Month	100 lbs. milk	1 lb. fat	100 lbs. milk	1 lb. fat	100 lbs. milk	1 lb. fat	100 lbs. milk	1 lb. fat	Milk	Fat
January	$ .64	$ .17	$ .65	$ .149	$ .94	$ .240	$ .56	$ .138	$ .68	$ .168
February	.68	.18	.67	.151	1.01	.253	.62	.160	.72	.179
March	.71	.18	.67	.165	1.21	.299	.59	.142	.76	.187
April	.71	.18	.71	.162	1.01	.234	.49	.121	.71	.171
May	.58	.145	.59	.132	.43	.096	.48	.113	.54	.125
June	.28	.075	.32	.076	.24	.053	.15	.038	.26	.064
July	.38	.095	.37	.078	.23	.053	.19	.049	.31	.072
August	.65	.155	.51	.114	.14	.033	.21	.051	.42	.098
September	.51	.125	.51	.106	.21	.052	.26	.066	.41	.094
October	.41	.105	.60	.140	.42	.098	.38	.091	.47	.112
November	.65	.175	.68	.159	.65	.153	.59	.135	.65	.157
December	.63	.155	.65	.164	1.03	.265	.63	.143	.71	.174
Average	$ .57	$ .145	$ .58	$ .133	$ .63	$ .152	$ .43	$ .104	$ .55	$ .133

[1] Bul. 52. [2] Bul. 35. [3] Bul. 26. [4] Bul. 43.

Since these data were gathered the cost of feeding stuffs has greatly advanced, so that the figures are only relatively valuable. They show that in 1897 the feed necessary to produce 100 lbs. of milk in March cost 76 cts., while when the same cows were on pasture in June it fell to 26 cts. Winter prices were again reached in November. The average feed cost for the year at the 4 stations was 55 cts. for 100 lbs. of milk and 13.3 cts. for a pound of fat. To get the present feed cost of milk and fat in the United States the figures should be increased by from 40 to 75 per ct.

657. Cost of keeping cows.—In addition to the cost of feed, the dairy cow should be charged with: (1) depreciation, interest, and taxes on the cow herself; (2) depreciation, interest, and taxes on barn; (3) depreciation and interest on barn tools and dairy implements; (4) cost of perishable tools and supplies, including bedding, ice, salt, brushes, record sheets, etc.; (5) proportionate cost of pure-bred sire; (6) cost of labor in caring for cow. These charges are estimated by various authorities as follows:

Cost of keeping cows in addition to cost of feed

	Lindsey, Mass. Station[1]	Trueman, Conn. Station[2]	Rasmussen, N. H. Station[3]	Cook and Minkler, N. J. Station[4]
	Dollars	Dollars	Dollars	Dollars
Int. and depreciation on cow	16.50	21.40 (cow and barn)	22.43 (cow and barn)	15.00
Barn for housing cow and feed	7.50			5.00
Int. and depreciation on tools and implements	1.15	.....	.....	.....
Perishable tools and supplies	9.00	7.00	7.57	3.65
Cost of pure-bred bull, per cow	4.00	3.00	3.79	1.93
Labor	35.00	33.60	33.73	30.34
	73.15	65.00	67.52	55.92*

[1] Mass. Bul. 145. [2] Conn. (Storrs) Bul. 73. [3] N. H. Exten. Bul. 2. [4] N. J. Rpts. 31, 33.
* Does not include charge for dairy apparatus, milk utensils, insurance, or incidental expenses.

These charges will vary greatly for the different sections of the country, depending on the price of labor, the shelter required, etc. The above figures will, however, give an approximate idea of the amount which should be added to the cost of feed to obtain the total cost of maintaining a cow for a year. In turn, the cow should be credited not only with the value of her product, either milk, or butter fat and skim milk, but also with the value of her calf and of the manure she produces.

CHAPTER XXIV

FEED AND CARE OF THE DAIRY COW

I. Feeding for Milk Production

Every dairyman knows that it is in late spring or early summer while on luxuriant pasture, that the dairy herd normally reaches the maximum production for the year. As Eckles[1] points out, this fact teaches that to secure the largest total yield of milk the dairyman should imitate these summer conditions as closely as possible during the other months of the year. The summer conditions which bring about the maximum production of milk and butter fat are:

1. An abundance of feed.
2. A balanced ration.
3. Succulent feed.
4. Palatable feed.
5. A moderate temperature.
6. Comfortable surroundings.
7. Reasonable exercise.

Upon the ability of the dairyman to maintain these favorable conditions for his herd thruout the year, depend in large measure the profits he will receive.

658. Generous feeding.—As before pointed out (**540-2**), the properly-bred and properly-fed dairy cow is the most efficient animal machine in existence for the conversion of the gross products of the fields and pastures into refined articles of the highest palatability and nutritive properties for human consumption. Yet many dairymen make the serious mistake of failing to supply this responsive animal machine with sufficient raw material, in the shape of feed, to ensure the most economical production. Since it requires about half of all the feed that even the good dairy cow will eat, merely to maintain her body, if she is given but little beyond the maintenance ration obviously only a small portion will be available for milk production. Since the 1000-lb. cow requires about 7.9 lbs. total digestible nutrients daily for her maintenance, as shown in Appendix Table V, the following table[2] shows the theoretical economy with which she will produce milk when given additional feed:

[1] Dairy Cattle and Milk Production, p. 257.

[2] Adapted from Eckles, Dairy Cattle and Milk Production, p. 261.

Economy of milk production on varying allowances of feed

	Nutrients for maintenance Lbs.	Available for production Lbs.	Proportion available for production Per ct.
Half ration, 7.90 lbs. dig. nutrients	7.90	0	0
Three-fourths ration, 11.85 lbs. dig. nutrients	7.90	3.95	33
Full ration, 15.80 lbs. dig. nutrients	7.90	7.90	50

Theoretically, when fed 7.9 lbs. digestible nutrients the 1000-lb. cow requires the entire amount for the up-keep of her body, leaving nothing for milk production. While she will continue for a time to yield some milk on this meager allowance, such return will be at the expense of her own body tissues. (**543**) When fed three-fourths of a full ration the cow can then use one-third of her feed for milk production, while if given a full ration half her feed is available for milk production.

659. The proper concentrate allowance.—The question of how much concentrates should be fed the dairy cow is of great economic importance to dairymen, for under normal conditions roughages are the cheap and concentrates the costly part of the ration. The amount of concentrates advisable depends first of all on the quantity and quality of the roughages furnished; and second, on the productive capacity of the cows. We have seen in the preceding chapter that a ration containing only legume hay and good corn silage will sustain a fair production of milk. Indeed, with ordinary cows such a ration may prove the most economical when concentrates are high in price. However, a cow of good dairy type and temperament will generally pay, thru the increased product, for a reasonable allowance of concentrates added to all the good roughage she will eat. Linfield of the Utah Station,[3] where alfalfa hay is largely fed for roughage, states that any excess over 6 lbs. of concentrates in the ration usually increases the cost of production. Stewart and Atwood of the West Virginia Station,[4] feeding timothy hay and corn silage for roughage, found that any increase in concentrates beyond 5 or 6 lbs. per cow daily did not bring corresponding returns. Hills of the Vermont Station,[5] after years of study of rations in which mixed hay and corn silage usually formed the roughage, concludes that 10 lbs. of concentrates will rarely pay over a smaller allowance, while 2 lbs. is too little, even with a full supply of roughage. When good quality roughage is plentiful, 4 lbs. of concentrates is likely to yield net returns nearly equal to an 8-lb. concentrate allowance; but when the after-production and the manurial value of the ration are considered, a concentrate allowance of 6 to 8 lbs. seems advisable. Woll and Carlyle in 2 trials at the Wisconsin Station[6] found that with hay and corn silage for roughage 8 lbs. of concentrates gave as good returns in milk and fat as 12 lbs.

Attention is directed to the relatively small allowance of concentrates recommended by the various investigators. This material reduc-

[3]Utah Bul. 43. [4]W. Va. Bul. 106. [5]Vt. Bul. 137. [6]Wis. Rpts. 1899, 1900.

tion from earlier recommendations tends to the more economical production of dairy products. The reader should note, however, that where small allowances of concentrates proved the most economical the roughage fed was always ample in quantity and desirable in quality, corn silage carrying more or less grain, and clover or alfalfa hay usually being employed. The dairyman who persists in feeding his cows wholly on such low-grade roughages as timothy hay, corn stover, etc., must pay the penalty by feeding from 10 to 12 lbs. of expensive concentrates daily if his cows are to maintain a reasonable flow of milk.

The wise dairyman will hold in mind that a good dairy cow in full flow of milk is expending fully as much energy as a horse at hard labor and this without cessation for many months. We know that the harder a horse works the more grain and the less roughage he must have, and the same is true for the cow. (**457**) In feeding, the aim should be to supply as much good roughage as the cow will readily consume, and to this add sufficient concentrates to keep the digestible matter up to the standard set by the scientists. (**Chapter VII**)

660. The ration should be properly balanced.—As we have seen (**310**), immature grass is rich in protein compared with carbohydrates and fat. Indeed Wolff based his standard, in which he advocated a heavy allowance of protein for the dairy cow, upon the composition of pasture grass. (**156-7**) While we have learned thru actual feeding trials that it is not necessary to furnish the dairy cow with as much protein as was advised by Wolff, her ration should nevertheless be much richer in protein than those for fattening or work animals. (**150**) Owing to the heavy demand for lime and phosphorus in milk production, the supply of these mineral nutrients must likewise be ample. Fortunately, both of these constituents are furnished in abundance by legume hay. The amount of protein it will pay to feed the dairy cow will depend, as has already been pointed out, on the relative prices of nitrogenous and carbonaceous feeds. In no case should the protein allowance fall far below the minimum amounts shown in Appendix Table V. In districts where protein-rich feeds are cheap, it is often more important to know how narrow a ration may safely be fed. Michels[7] and McNutt[8] found in trials at the North Carolina Station that rations containing 4 to 6 lbs. of cottonseed meal and having nutritive ratios as narrow as 1:4 were entirely satisfactory.

661. Cows should be fed individually.—So pronounced is the tendency to milk production in cows of marked dairy temperament that, in spite of the most liberal feeding, they will rarely lay on flesh when in full flow of milk, provided their ration is well balanced. On the other hand, cows of ordinary capacity may easily be overfed, in which case they will store the surplus nutrients in the form of body fat, rather than increasing their milk production. Since even in a well-bred and well-selected herd the different cows vary widely in productive ability, for the greatest

[7] N. C. Bul. 213. [8] Proc. Amer. Soc. Anim. Prod., 1914.

profit the cows must be fed as individuals, rather than each animal being given the same ration. Only under exceptional conditions does this mean, however, that it is practicable to compute a balanced ration for each different animal. Ordinarily it will suffice to determine what amounts and proportions of feeds should be used to provide an economical ration that will meet the standards for the average of the herd, in the manner shown in Chapters VII and VIII. Each cow may then be given all the roughage she will eat, and the allowance of concentrates adjusted according to her production. A dairy cow will usually consume about 2 lbs. of dry roughage of good quality daily per 100 lbs. live weight, or 1 lb. of dry roughage and 3 lbs. of silage. Common rules for feeding concentrates are:

1. Feed 1 lb. of concentrates per day for each pound of butter fat the cow produces per week, or
2. Feed 1 lb. of concentrates per day for each 3 to 4 lbs. of milk, depending on its richness, or
3. Feed as heavy an allowance as the cow will pay for at the ruling prices for feeds and products, increasing the allowance gradually until she fails to respond by an increase in production which will cover the increase in cost.

The first 2 rules apply only when abundant roughage of good quality is supplied. Heavy producers require a narrower nutritive ratio than ordinary animals, and hence it may be advisable to alter the character of the grain mixture for them. It is also wise to feed a more nitrogenous concentrate allowance to cows which show a tendency to fatten, while animals which are losing flesh should receive a larger proportion of the carbonaceous concentrates, such as the farm-grown grains.

662. Feeding concentrates on pasture.—The economy of feeding concentrates to cows on pasture has been studied at a number of stations. Shelton and Cottrell of the Kansas Station[9] found that feeding grain to cows on pasture did not directly pay, even tho the yield of milk was increased as much as 31 per ct. Moore of the Mississippi Station,[10] on feeding 3 lbs. of cottonseed meal and 4 lbs. of wheat bran daily per cow to a dairy herd on pasture, found that the increased milk flow did not justify the expense, tho the firmness of the butter was greatly improved by feeding the cottonseed meal. At the Utah Station[11] Linfield found that cows getting some concentrates while on pasture, at first showed no great advantage therefrom; later the effects of such feed became apparent, the difference being very marked by the following winter.

Roberts of the New York (Cornell) Station[12] found that cows fed concentrates while on luxuriant pasture gave less milk and no more fat than those on grass alone. With luxuriant pasture except for a short period, both lots did equally well. Grain-fed cows that were fed grass for soilage gave just enough more milk than others fed no grain to pay for the concentrates fed. The study was then transferred to a nearby dairy

[9] Kan. Rpt. 1888.
[10] Miss. Bul. 70.
[11] Utah Bul. 68.
[12] N. Y. (Cornell) Buls. 13, 22, 36, 49.

farm. A herd of 16 cows lightly fed the previous winter was divided into 2 lots of 8 cows each, all grazing on the same pasture. Each cow in Lot I was given 4 quarts daily of rich concentrates, while those in Lot II received none. When the grass began to fail in August soilage was fed. The returns for 22 weeks are as follows:

Feeding concentrates to cows on pasture

	Lot I Pasture with concentrates	Lot II Pasture without concentrates
Concentrates fed, pounds	5,200	.....
Milk yield, pounds	22,629	17,698
Excess of milk in favor of Lot I, pounds	4,931	.....
Gain in weight per cow, pounds	166	113
Average per cent fat in milk	4.67	4.70
Average per cent total solids	14.08	14.19

In this trial the pastured cows getting concentrates gave 28 per ct. more milk than those getting no concentrates, and each pound of concentrates fed returned about 1 lb. of milk.

The following year no concentrates were fed to either lot while on pasture. The 6-months yield from 6 cows that remained in each lot was as follows:

Residual effect of feeding concentrates

	Lot I Fed concentrates previous year	Lot II Fed no concentrstes previous yesr
Average yield per cow, 6 months, pounds	3,440	2,960
In favor of Lot I, pounds	480	....

Tho getting no concentrates, Lot I returned 480 lbs., or 16 per ct., more milk than Lot II. Roberts holds that this was due to feeding concentrates the preceding year. The benefits were especially marked in the case of the heifers, the 2- and 3-yr.-olds fed concentrates the year before developing into better animals than their mates which had been fed no concentrates the previous year while on pasture.

In a test on the Elmendorf Farm, Hooper of the Kentucky Station[13] found that one lot of cows, fed 4 lbs. of a grain mixture per head daily while on bluegrass pasture, returned 19 cents per head daily more profit over cost of feed than another lot on bluegrass pasture alone. A third lot, fed 10 lbs. of corn silage per head daily, returned only 2 cents more profit than the cows on pasture only, and a fourth lot, fed 4 lbs. of grain and 10 lbs. of silage, but 12 cents more over the cost of feed.

Foster and Latta found at the New Mexico Station[14] that altho the production was increased by feeding grain to cows on good mixed pasture, the additional product did not pay for the greater cost of feed.

The advisability of feeding concentrates to cows on ample pasture thus depends entirely on the relative cost of pasturage and concentrates,

[13] Ky. Bul. 171. [14] N. M. Bul. 98.

the price secured for dairy products, and the productive capacity of the cows. While the animal giving only an average quantity of milk may not pay for such addition of concentrates, the heavy-yielding cow can not continue long on her level of high production without some concentrates, unless the pasture be unusually luxuriant. Eckles[15] concludes that a Jersey giving as much as 20 lbs. of milk per day, or a Holstein yielding 25 lbs. of milk or more, should be fed some concentrates on pasture. The amount to be fed must be left to the business judgment of the individual dairyman.

663. Supplementing short pasture.—It is of the greatest importance that additional feed be provided for dairy cows when pastures become parched and scant in midsummer. Corn or sorghum silage usually furnishes the cheapest feed for this purpose (**412**), but where this is not available soiling crops should be specially grown. (**418-22**) When the pasturage is scant, the increased milk flow will fully and directly compensate for additional succulence or other feed supplied. Where the pastures are short, unless soilage crops or concentrates are fed, the milk flow will surely decrease, and, even should the pastures improve later, the cows cannot be brought back to their normal milk flow. The greater value to the pastures of the droppings from concentrate-fed cows will often prove the deciding factor with thoughtful dairymen. The residual effects upon the cows from concentrate-feeding on pastures, as pointed out by Roberts and Linfield, are most important and should not be overlooked.

664. Succulent and palatable feed.—The great importance of succulent feed for the dairy cow has been shown in the trials which have been reviewed in the preceding chapter. (**629-43**) These show clearly that it pays to provide succulence, either corn silage or roots, for winter feeding to take the place of the green grass the cows get in summer. The value of succulent feed is due in no small measure to its beneficial laxative effect and to its palatability, which undoubtedly tends to stimulate digestion. (**109**) In general, not only should succulence be supplied, but the rest of the ration for cows yielding a good flow of milk should be as palatable as possible. Such roughages as timothy hay, straw, and corn stover may be used in limited amount, but for the best results should not constitute the chief roughage. As has been pointed out before, concentrates which are not relished when fed alone may be mixed with well-liked feed, the whole forming a palatable mixture. (**594, 608**)

The concentrate allowance should be composed of a reasonable number of feeds, for a mixture is relished better than only a single kind of grain or roughage. It is also best to feed at least 2 kinds of roughage. The most successful dairymen maintain that when a satisfactory balanced ration has been provided, it is then best to make as few changes as possible.[16]

[15] Dairy Cattle and Milk Production, p. 256.

[16] Haecker, Minn. Bul. 130; Eckles, Dairy Cattle and Milk Production, p. 284.

665. Water.—Cows require a large amount of water for their bodily needs and for the milk. Eckles[17] found that cows in milk drank 4 times as much water as when they were dry and farrow. Collier of the New York (Geneva) Station[18] found that cows obtained 4.6 lbs. of water in feed and drink for every pound of milk they yielded. At the Pennsylvania Station[19] Armsby found that cows averaging about 750 lbs., fed fresh grass in stalls where the temperature averaged 70° F., drank about 60 lbs. of water each daily. Others fed dry grass where a temperature of 73° F. prevailed drank 107 lbs. When at the Wisconsin Station[20] the same investigator found that cows drank more water on protein-rich than on protein-poor rations. In general the water provision for dairy cows should be about 100 lbs., or 12.5 gallons, per head per day. Heavy yielding cows will require much larger amounts, for Eckles found that a Holstein cow producing about 100 lbs. of milk per day on a ration of 18 lbs. alfalfa hay, 10 lbs. corn silage, and 14 to 20 lbs. of concentrates drank from 216 to 307 lbs. of water daily. As cows are creatures of habit, those of ordinary productive capacity will have their needs supplied if once each day they have opportunity to secure easily all the water they then can drink. Most authorities agree that high-producing animals should have water at least twice a day. The supply should be of good quality and close by, so the cows will not be forced to travel far. The dairyman who boasts of a spring or creek to which his cows must daily journey, often in inclement weather, will find a conveniently located well with windmill or gasoline lift far superior. (**103**)

Opinions differ as to the advisability of warming water for cows in winter. Owing to the heavy rations cows in milk consume there is a large amount of heat produced in their bodies thru the energy expended in the mastication, digestion, and assimilation of the feed. When comfortably housed probably little or no nutrients need be burned in the body for warming the water drunk in winter, provided it is no colder than that from a deep well. Hills of the Vermont Station[21] found no benefit from warming water for cows in comfortable quarters. An important reason for warming the water for heavy-yielding cows is that unless this is done they may not drink a sufficient quantity to make possible the maximum production of milk. There has been much discussion in regard to watering the cows in their stalls. Hayward of the Pennsylvania Station[22] and Hills of the Vermont Station[23] found no advantage in keeping water continuously before cows, instead of allowing them to drink once daily. In regions with severe winters most authorities recommend that the animals be watered indoors when the weather is so inclement that it is not desirable to turn them out for exercise. Some devices for stall-watering are actually dangerous, for tho the drinking basin may be kept clean, the supply pipe coming into it from below re-

[17] Dairy Cattle and Milk Production, p. 242.
[18] Proc. of "N. Y. Farmers," 1892-3.
[19] Penn. Rpt. 1888.
[20] Wis. Rpt. 1886.
[21] Vt. Rpt. 1907.
[22] Penn. Bul. 56.
[23] Vt. Rpt. 1907.

tains saliva and particles of food which may drop into the basin. Such material quickly putrefies, lines the pipes with a slimy mass, and contaminates the water which rises into the basin.

666. Salt.—The studies of Babcock and Carlyle, already reviewed (**101**), show that dairy cows require salt to thrive. The amount to be fed will vary according to the salt content of the feeding-stuffs in the ration. More should be supplied when heavy allowances of rich concentrates are fed. These investigators found that when allowed free access to salt cows consumed about 1 ounce daily, and conclude that 0.75 ounce daily per 1,000 lbs. live weight, with 0.6 ounce in addition for each 20 lbs. of milk, is generally sufficient. The salt allowance may be regularly mixed with the feed, or it may be placed where the animals can consume it as their appetite directs.

II. Hints on Caring for Dairy Cows

667. Shelter and comfort.—The steer, gorged with feed and every day adding to the heat-holding fat layer just beneath the skin, prefers the yard or open shed to the stable. (**727**) The dairy cow stands in strong contrast, her system being relaxed thru the annual drain of maternity and the daily loss of milk, the combination severely taxing her digestive and assimilative powers and drawing heavily on her vitality. In winter the cow should be comfortably housed in a well-lighted, well-ventilated stable, the temperature of which should range from 40° to 50° F. (**91**)

To preserve the health of the herd as well as for sanitary reasons it is advisable to have not less than 4 square feet of window glass for each animal. It is well to clean and disinfect the stable thoroly at least once a year, to check any possible spread of disease.[24] As the dairy cow is a sensitive, nervous animal the wise dairyman will provide comfortable stalls or swinging stanchions, and see that the cows are well bedded. The benefits from dehorning have already been pointed out. (**569**) The sharp decline in milk production which often occurs in midsummer, charged by many to the annoyance of the cows by flies, undoubtedly is more often due to a shortage of feed. Beach and Clark of the Connecticut (Storrs) Station,[25] and Eckles of the Missouri Station,[26] found no increase in milk production when the herd was sprayed with a fly repellant, tho the cows were less restless during milking when they had been previously sprayed.

668. Preparation of feed.—The cow giving a large flow of milk is working as hard as the horse ever does, and, this true, any grain given her should be ground or crushed if not otherwise easy of mastication and digestion. Corn and oats should generally, and wheat, rye, barley, kafir, and milo always, be ground or "chopped," and roots should be sliced or pulped. Because the cow takes kindly to dry feed and everything which enters the paunch is quickly soaked and softened, there

[24] Lindsey, Mass. Bul. 145. [25] Conn. (Storrs) Bul. 32. [26] Mo. Bul. 68.

seems no occasion for feeding slops, nor is there any advantage from cooking ordinary feeding stuffs. (**423-31**)

669. Frequency of feeding.—The ample paunch and the considerable time needed for rumination teach that the common practice of feeding cows twice daily, morning and evening, with possibly a little roughage additional at midday, is a reasonable one. Those who give their cows first a little of this and then a little of that, busying themselves all day in the stable, usually ascribe success to their irksome system of feeding, when in truth it is due to good care generally and not to the particular system of feeding. Habit is strong with the cow, and a simple system of feeding and stable management once established should be rigorously continued. (**571**)

670. Order of feeding.—In the roomy paunch hay and grain, eaten separately, are rapidly and thoroly commingled by the churning action of that organ and gradually softened in the warm, abundant liquid it contains. This true, the particular order of feeding roughages and concentrates is not important. While the particular time of feeding is not of prime importance, it is essential that the cows be fed at regular intervals. If then satisfied they are content until the time for another feed. The cow seems best satisfied when the concentrates are given first, and these out of the way, she proceeds to dispose of the roughage before her. Some cows give down their milk more freely when eating their concentrate allowance, but this is probably due to habit, for others which have always been fed their concentrates either before or after milking seem equally contented. Hay or other dry forage is usually not fed till after milking, because it fills the air with dust. Silage, turnips, cabbage, or other feeds with a marked odor should be given only after milking.

671. Regularity and kindness.—To skillful feeding and wholesome quarters the successful dairyman adds regularity and kindness. On this point Babcock of the Wisconsin Station[27] writes: "I would recommend, therefore, in order to obtain the best results from any cow, that first of all she be treated kindly, all sources of excitement being avoided so far as possible. She should also be fed and milked at regular intervals by the same person, and all conditions should be maintained as nearly uniform as possible at all times. It is my opinion that kind treatment and pleasant surroundings will have a greater influence upon the quality of milk than the kind of food, provided the ration given contains sufficient nutriment for the maintenance of the animal."

While milking is usually regarded as a simple task which anyone can do, there may be a great difference in the returns which different milkers get from the same cow. A cow should be milked quietly with the dry hand, and stripped out thoroly, the milker bearing in mind that the last-drawn milk carries about 10 times as much fat as that drawn first. (**552**) If the teats are chapped or injured, vaseline or other ointment should be

[27] Wis. Rpt. 1889.

applied, and the milker should be especially patient, lest the evil habit of kicking be developed.

On the general treatment of the herd Haecker of the Minnesota Station[28] offers the following sage advice:

"We know of many instances where the best of dairy cows were kept, and where good methods of feeding were practiced; and still results fell far short of what might reasonably be expected, simply because the animals did not receive that kindly treatment which is so essential to a cow giving much milk for a long period. The herd as a whole should always be moved slowly. Never hurry a cow, or strike her or speak loudly and harshly. A gentle voice and a caressing touch are quite as potent as is digestible protein. If you so handle the cows that they are fond of you, you have learned one of the most important lessons that lead to profitable dairying. The most successful milk-producers are always in close touch with every cow in the herd. The milk-producer has to do with motherhood, in which affection always plays an important part. A cow's affection for the calf prompts the desire to give it milk; if you gain her affection, she will desire to give you milk. If you have not been in the habit of caressing the cows, the time to inaugurate the practice is when they approach the time of calving, as it is at that particular time when they take kindly to grooming and to gentle rubbing of the udder.

"Each cow should have a name, which should always be spoken when approaching her. This one point counts for much in the successful handling of a herd. Suppose the cows are slowly filing into the barn, and you see that Rose is about to go into the wrong stall. A quick call of "Rose!" will attract her attention, and she will forget that she was about to go into her neighbor's stall to steal a mouthful of her feed. If Rose, when in the yard, is about to hook another member of the herd, and just at that moment hears her name called, she will forget what she was about to do. Again, suppose the herd is slowly wending its way down the lane to the pasture, and someone has thoughtlessly left a side gate open, leading into a grain field. Rose is in the lead, and, as you see her turning toward the open gate, a quick, sharp call of "Rose!" will exert a wonderful influence in bringing her back into line. It is by such methods that a herd can be gradually taught to do the right things, to save you many steps, and at the same time bring a larger return."

III. Feed and Care Before and After Calving

672. Giving the cow a rest.—Practically all observing dairymen agree that it is most profitable to give the dairy cow a rest between lactation periods, for experience has shown that she will produce more milk annually if dry 6 to 8 weeks than if milked continuously. Carroll of the Utah Station,[29] studying data secured with 496 cows in a cow-testing

[28] Minn. Bul. 130. [29] Utah Bul. 127.

association, found that cows dry for 2 months produced more fat and returned more profit than those allowed to rest but a single month. Eckles[30] recommends that under ordinary conditions the cow be dry 6 weeks and preferably 2 months if in a thin condition. Dairymen differ as to the best length of lactation period, but so far as the available data warrant conclusions, there is no apparent difference in the annual returns from cows again freshening 9, 10, or 12 months after calving, providing they are allowed to be dry for 6 weeks to 2 months.[31]

To avoid injury to the udder the cow should be dried off gradually. It is well to milk only once daily for a few days, not stripping the udder out clean; then but once in 2 days for 3 or 4 days, after which the interval is lengthened to twice a week. When the milk yield is decreased to 10 lbs. per day or less, according to Eckles,[32] milking may be entirely discontinued. The udder will fill for a few days, but the milk will be gradually reabsorbed, and no harm will result. If the cow continues to produce more than 10 lbs. a day her concentrate allowance should be withheld and only poor roughage, like timothy hay, fed until the flow is checked.

673. Feed for the cow when dry.—To ensure a good flow of milk the cow should be in good condition at freshening, as has already been pointed out. (**557**) When the animal is in a thrifty condition there is also less trouble in calving. Only sufficient concentrates should be fed to put the cow in proper flesh, for if she has been heavily fed with rich concentrates while giving milk, a helpful change may now be made to a ration which will rest and cool the digestive tract. Just previous to calving time the feed should be slightly laxative, tho if on pasture no especial attention need be given to this point. For cows that freshen while housed nothing is better than legume hay and silage, with a couple of pounds of concentrates added, if necessary. The cow soon to calve should have exercise, but should not be chased by dogs or driven thru narrow gates.

674. Gestation period; calving time.—The average gestation period of the cow is placed by various authorities at from 280 to 285 days. Wing of the New York (Cornell) Station[33] found the average of 182 recorded gestation periods for the cow to be 280 days, ranging from 264 to 296 days. About an equal number of births occurred on each day from the 274th to the 287th, inclusive. The gestation period was not different for the sexes.

Unless the herd is at pasture the cow should be kept in a clean, comfortable, well bedded box stall at calving time. If her bowels are not moving freely give a drench of Epsom salts. As parturition approaches the udder will become distended and hard, and when the muscles on each

[30] Dairy Cattle and Milk Production, p. 229.
[31] Carroll, Utah Bul. 127.
[32] Dairy Cattle and Milk Production, p. 230.
[33] N. Y. (Cornell) Bul. 162.

side of the tail head relax, leaving a hollow on each side, the calf may be expected within 24 hours, or 3 to 4 days at the longest. The cow should not be molested during calving unless assistance is required. For 2 or 3 days after calving her drinking water should be lukewarm, and she should be protected from cold drafts, for her vitality is low. The feed for the first few days should be limited in amount and cooling and laxative in nature. Besides legume hay and silage she may be given such feeds as bran (often fed as a mash), oats, and linseed meal. High-producing cows should be watched closely for signs of milk-fever, and the air treatment, the great boon to dairymen, used if necessary.

The yearly production of the cow depends in a large measure on the feed she receives during the first month after calving. The concentrate allowance, small at first, should be increased gradually, at the rate of a a half-pound every other day until the full allowance is reached, for heavy feeding immediately after calving is apt to lead to digestive disturbances. If the udder is swollen and hard, even more care should be used in getting the cow to the full ration.

It is quite customary to save the seventh milking after the cow calves for human use, altho sometimes the milk is not normal before the eighth or ninth milking. A simple test for normal milk, advised by *Hoard's Dairyman,*[34] is to heat a small quantity to boiling; if the sample does not thicken, due to the high content of albumin, the milk is usable. (**115**)

675. Fall vs. spring freshening.—Spring-fresh cows yield most of their milk when low prices prevail for dairy products and the dairyman is busiest with the crops. In winter such cows yield only a small flow at most. On the other hand, the fall-fresh cow gives a large supply of milk during the winter, and flushes again with the stimulus of pasture in springtime. Fall-fresh cows should annually yield from 10 to 15 per ct. more milk than those calving in the spring. When cows freshen in the fall more of the work of milking comes in the winter when farm work is slack. More time can be given to the raising of the calves, and less trouble will be experienced from scours than during the summer. Fall-dropped calves are large enough by spring to make good use of pasture and better able to stand the hot weather. Under this system a larger supply of skim milk is available for the young spring pigs.

IV. Reducing the Cost of Milk Production

676. The burden of dairying.—So large are the feed and labor bills on many dairy farms, especially in the older settled portions of our country, that when these have been met little remains for the proprietor. To reduce the cost of milk production to a point where a reasonable profit may be made the dairyman must first of all cull out all cows whose product will not under any conditions pay for their keep. (**544-7**) An analysis of his expenses will then show that in nearly every case it is the

[34] Hoard's Dairyman 43, 1912, p. 865.

feed bills and not those for labor that are the real burden. Whoever would improve his condition must cut the monthly feed bills to the minimum, not thru parsimonious feeding, but by growing great crops of the best feeding stuffs. With rare exceptions the dairy farm should produce all the roughage and the greater part of the concentrates the herd consumes. Growing the needed feeding-stuffs will increase labor and fertilizer bills, but such shifting of expenditure should prove highly economical in the end. Indian corn or the sorghums flourish over a large portion of the United States, furnishing both concentrates and roughage, and one or more kinds of legumes, furnishing protein-rich roughage, can be successfully grown on every farm. By the judicious and generous use of these best allies of the dairyman the great burden of the feed bills can be lessened.

677. Selecting economical rations.—In Chapter XXII the values of the different feeding stuffs for the dairy cow have been discussed in detail and with the data there given the dairyman can readily determine the most economical rations to employ. In computing rations the general principles which have been pointed out in Chapter VII should always be considered. (**158–67**)

To illustrate the widely different value for milk production of rations which are balanced so far as amount and proportion of digestible nutrients are concerned, the following rations, which meet the requirements for a 1000-lb. cow giving 25 lbs. of 4 per ct. milk, are presented:

Rations that are balanced, but of unequal value for milk production

	Dry matter	Digestible protein	Total dig. nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	
A poor ration				
Timothy hay, 20 lbs.	17.7	0.60	9.70	
Dent corn, 2.0 lbs.	1.8	0.15	1.71	
Wheat bran, 7.5 lbs.	6.7	0.94	4.56	
Linseed meal, 1.5 lbs.	1.4	0.45	1.17	
	27.6	2.14	17.14	1 : 7.0
A fair ration				
Clover hay, 22.0 lbs.	19.2	1.67	11.22	
Dent corn, 7.0 lbs.	6.3	0.52	5.99	
	25.5	2.19	17.21	1 : 6.9
A good ration				
Corn silage, 35.0 lbs.	9.2	0.38	6.20	
Clover hay, 15.0 lbs.	13.1	1.14	7.65	
Dent corn, 3.0 lbs.	2.7	0.22	2.57	
Cottonseed meal, choice, 1.0 lb.	0.9	0.37	0.78	
	25.9	2.11	17.20	1 : 7.1

In the first ration, where timothy hay, low in protein and not palatable to the cow, supplies the roughage, 11 lbs. of expensive concentrates are required to provide the additional nutrients needed. Even then this expensive ration is unsatisfactory, for timothy hay is a poor cow feed at best. (**623**)

The second ration of clover hay and ground corn is better and less expensive than the first. Such a ration is theoretically ample, but there should be a larger variety of feeding-stuffs to make it satisfactory. (**163**)

The last ration is much superior. Legume hay and corn silage make a combination of roughages which is most palatable and acceptable to the cow, and there is further required only 4 lbs. of concentrates to balance the ration. As has been pointed out (**659**), when the after-effect of the ration on the animal and on the manurial value of the ration are considered, it may be advisable to feed at least 6 lbs. of concentrates to cows of good dairy temperament, when concentrates are not too high in price. The third ration, containing only 4 lbs. of concentrates, is less expensive and more desirable than the second one, and far less expensive and much more desirable than the first. Altho all are theoretically "balanced," the last one is not only the lowest in cost, but if put to the test will probably produce from 20 to 30 per ct. more milk than the first, and somewhat more than the second.

CHAPTER XXV

RAISING DAIRY CATTLE

I. The Skim-Milk Calf

The profitableness of dairying depends to a large degree upon the careful rearing of the heifer calves from the best cows in the herd and sired by a pure-bred bull of quality. Improvement of the herd can best be made by replacing the discards with well-bred, home-reared heifers of greater productive capacity. Starting with common cows, one may by this means in a few years build up a high-producing herd. On the other hand, the dairyman who replenishes his herd by purchase must pay high prices for animals which, tho of good appearance, may not be well-bred. Careful dairymen are loath to part with their best heifers, preferring to keep them to improve their own herds. Another important reason for rearing the heifers is that it is much easier to keep the herd free from such diseases as tuberculosis and contagious abortion when the heifers are home-raised, than when they are continually being brought in from outside sources.

Tho the value of the calf at birth depends primarily on its breeding, the feed and care it receives while young are fully as important factors in deciding its future usefulness in the herd. The general principles of calf-rearing, which are presented in this chapter, are well founded upon scientific trials and practical experience, but the raising of calves will ever remain an art, in which much depends on the skill and judgment of the feeder, who should study the individual requirements of the animals, rather than blindly following hard and fast rules.

678. Raising calves on skim milk.—The fat of milk is so valuable that but few dairy calves are now reared on whole milk when skim milk is available. Those prejudiced against the rearing of calves on skim milk by the sight of unthrifty, undersized skim-milk-fed specimens should know that such results are not due to the removal of the fat from the milk on which they were fed, but to the ignorance or carelessness of the feeder. Careful dairymen have abundantly demonstrated that skim-milk calves, properly fed, develop into as good cows as those fed whole milk until weaning time.

679. Skim milk vs. whole milk.—In a trial at the Kansas Station[1] Otis fed one lot of calves skim milk and a second whole milk, while a third lot ran with their dams at pasture. Those getting skim milk or whole milk were given in addition equal parts of corn meal and kafir meal, with alfalfa hay for roughage. After weaning, all the calves, which were

[1]Kan. Bul. 126.

steers, were placed in the feed lot and given the same feeds until 1 year of age. The following table shows the rate and cost of the gains of the calves in each lot.

Rate of gain of calves variously fed up to 1 year of age

How fed	Before weaning				210 days in feed lot, after weaning	
	No. of calves	Length of time	Av. daily gain	Feed cost of 100 lbs. gain	Av. daily gain	Concentrates per 100 lbs. gain
		Days	Lbs.	Dollars	Lbs.	Lbs.
Skim milk.........	10	154	1.5	2.26	2.1	439
Whole milk........	10	154	1.9	7.06	1.9	470
Running with dam .	22	140	1.8	4.41	2.0	475

The skim-milk calves, tho not gaining so rapidly as the others up to weaning, cost less for a given gain than either of the other lots. In the feed lot the skim-milk calves made the most rapid gains and also the most economical ones, measured by the feed consumed. Otis reports that the 22 calves running with their dams lost 73 lbs. the week following separation at weaning time, requiring several weeks to recover this loss. In estimating the cost of the several lots before weaning, skim milk was valued at 15 cents per 100 lbs., and whole milk at 21.1 cents for each pound of fat it contained. Hay was rated at $4 per ton, and concentrates at $10. The cost of a calf running with its dam until weaned was placed at $12, and of one raised on skim milk at $5.27.

Hooper of the Kentucky Station[2] fed one lot of 6 calves whole milk in a 79-day trial, while another was changed in a few days to skim milk. Each lot received in addition 0.5 lb. per head daily of a mixture of equal parts corn meal, bran, and linseed meal, besides what hay they would eat. The skim-milk calves made slightly larger gains than those fed whole milk, and were just as thrifty.

680. Supplements to skim milk.—It has already been pointed out that whole milk is the ideal food for young animals, being rich in protein and ash. (**115**) Skim milk differs in composition from whole milk only in having had most of the fat removed. Provided no water has been added, this will increase the percentage of water, protein, sugar, and ash over that in whole milk. Owing to the removal of the fat, skim milk is a much more nitrogenous food than whole milk, having a nutritive ratio of 1:1.5 compared with 1:4.4 for unskimmed milk. Not appreciating this fact, early investigators usually advised supplementing skim milk with nitrogenous concentrates, such as linseed meal and wheat bran. It is evident, however, that in a skim-milk supplement the need is not for additional protein, but for an abundance of energy-giving carbohydrates or fat to replace the fat removed from the milk.

While various fats and oils may be used to supplement skim milk, the cereal grains, rich in carbohydrates, are cheaper supplements than the

[2]Ky. Bul. 171.

oils available for calf feeding. Moreover, unless oil is fed as an emulsion with the milk it is apt to produce indigestion and scours, for young animals in general have but limited ability to digest fat. (**117**) At the Massachusetts Station[3] Lindsey found cod-liver oil added to skim milk unsatisfactory, the calves sometimes refusing the combination. A cheap grade of oleomargarine was heated to 110° F. and mixed with skim milk by churning. It was found that 1 ounce of oil per quart of skim milk was all that the calf could take without indigestion being produced. Cottonseed oil and corn oil to the amount of one-half ounce per quart of milk were fed without bad effect. A calf fed skim milk containing 1 part oleo and 2 parts brown sugar gained over 2 lbs. daily, with kidneys well covered with fat. Calves thus fed were superior to those receiving skim milk only, but not equal in fatness to sucking calves.

681. Farm grains as skim-milk supplements.—During 3 trials lasting 60 to 90 days at the Iowa Station[4] Curtiss fed skim milk fresh from the farm separator, having a temperature of 90° F., to Shorthorn and Holstein calves weighing 180 to 200 lbs. An average allowance of 15.4 lbs. of milk and 2.9 lbs. of hay was given to each, with either linseed meal, sieved ground oats, or corn meal with a little flax seed. Eight calves were fed each ration with the following results:

Fresh separator skim milk with various concentrates for calves

Average concentrate allowance	Av. total gain	Av. daily gain	Dry matter per 100 lbs. gain	Feed cost of gain per lb.	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Cts.	
Lot I, Linseed meal, 1.2 lbs. . .	109	1.47	339	2.8	1 : 2.6
Lot II, Oat meal, 1.5 lbs.	116	1.57	337	2.1	1 : 3.6
Lot III, Corn meal, 1.3 lbs. Flax seed, 0.1 lb.	116	1.56	330	2.2	1 : 4.0

These trials show no advantage in using a protein-rich concentrate such as linseed meal to supplement skim milk. In one of the trials corn meal alone produced larger and cheaper gains than linseed meal, oat meal, or corn meal and flaxseed. Curtiss concludes: "In the corn-belt states, with their surplus of corn and oats, there is no necessity for the purchase of a high-priced nitrogenous product to be used in supplementing the skim-milk ration."

Cottrell, Otis, and Haney of the Kansas Station[5] report that kafir meal, given dry, is particularly suited to feed with skim milk because its constipating nature overcomes the scouring tendency of the milk. (**237**)

Fain and Jarnagin at the Virginia Station[6] found barley an excellent supplement to skim milk. (**226**) Bran was helpful in teaching the calves to eat grain, but no benefit, either in the rate of gain or the appearance of the calf, was secured from adding it to a ration of shelled corn and skim milk. (**218**)

[3] Mass. Rpts. 1893, 1894. [4] Iowa Bul. 35. [5] Kan. Bul. 93. [6] Va. Bul. 172.

At the Kansas Station[7] Otis found ground soybeans unsatisfactory as a skim milk supplement for calves on account of their laxative nature. (**256**) Duggar of the Alabama Station[8] reports that rice meal is decidedly inferior to corn meal as a supplement to skim milk. Because it was impossible to get the calves to eat sufficient rice meal, one-third wheat bran was added. (**234**)

Cottonseed meal is not a safe feed for young calves, as is shown elsewhere. (**249**) Soule of the Georgia Station[9] states that after calves are 6 to 8 months old they may be fed 2 lbs. per head daily with silage and such feeds as shredded corn stover and oat straw. The allowance should be gradually increased, starting with 0.5 lb. per head daily.

682. Grinding grain for calves.—Otis[10] found that calves fed whole corn were less subject to scours and more thrifty than when given ground corn (corn chop). Ground kafir gave better results than whole kafir, owing to the hardness of the seeds.

At the Virginia Station[11] Fain and Jarnagin secured a gain of 1.4 lbs. daily when feeding calves corn meal with skim milk, and 1.6 lbs., or 14 per ct. more, when whole corn was used. Kildee of the Iowa Station[12] prefers whole oats to ground oats for calves. In teaching calves to eat, ground grain is usually fed, and whole corn or oats substituted later. After the calves are several months old they masticate their feed less thoroly, and grinding corn or oats may then be profitable.

683. Various concentrate mixtures with skim milk.—Woll conducted 2 trials, both with 2 lots of 8 dairy calves each, at the California Station[13] to compare the value of a mixture of equal parts ground barley, oats, and middlings with a mixture of 1 part linseed meal and 2 parts each of ground barley, oats, and middlings, when fed with skim milk and hay:

Value of linseed meal added to concentrate mixture for calves

Concentrate mixture	Average ration: Concentrates Lbs.	Average ration: Skim milk Lbs.	Hay* Lbs.	Age at beginning Days	Wt. at beginning Lbs.	Daily gain Lbs.
First trial, 70 days						
Without linseed meal ...	0.9	12.1	2.3	40	126	1.14
With linseed meal......	0.9	12.1	2.2	31	127	1.27
Second trial, 84 days						
Without linseed meal....	2.01	11.3	5.7	115	201	1.84
With linseed meal......	1.96	10.8	5.7	106	200	1.74

*Not all of the hay offered was consumed.

In the first trial the lot receiving linseed meal made slightly the larger gains, while in the second trial the results were reversed. There was no difference in the appearance or thrift of the 2 lots. Woll concludes that there was no decided advantage from including linseed meal in the ration for skim milk calves so far as the immediate gains are con-

[7]Kan. Bul. 126.
[8]Ala. Bul. 128.
[9]Breeder's Gaz., 63, 1913, p. 81.
[10]Kan. Bul. 126.
[11]Va. Bul. 172.
[12]Iowa Cir. 16.
[13]Information to the authors.

cerned. The linseed meal, however, aids somewhat in making the mixture palatable.

To determine whether any advantage resulted from including a large variety of feeds in the concentrate allowance for skim-milk calves, Otis at the Kansas Station[14] fed one lot of 10 calves equal parts of shelled corn and ground kafir, while another was fed a mixture of 10 parts shelled corn, 10 parts ground kafir, 6 parts whole oats, 6 parts bran, 2 parts linseed meal, and 0.5 part dried blood. The corn and kafir mixture produced larger gains than that supplying a greater variety of feeds. In another trial no advantage resulted from adding either ground flaxseed or a proprietary calf feed to ground kafir for skim milk calves. With Otis we may therefore conclude: "While calves may do well on high-priced concentrates, they are unnecessarily expensive and give no better results than the cheaper carbonaceous grains, as corn, barley, oats, kafir, or sorghum."

For calves up to 3 or 4 months of age some dairymen advocate feeding ground flax seed, either added directly to the milk or made into a jelly with boiling water and then mixed with the milk, about a tablespoonful of the flax seed being used to each quart. Others report equally good results from starting directly on farm grains.

From experiments at the Louisiana Station[15] Woodward and Lee conclude that "blackstrap," or cane molasses, cannot be used as a supplement to skim milk for calf feeding in sufficient quantity to be of any practical value, as it tends to produce scours. **(279)**

In Europe the use of "saccharified" starch, or starch which has largely been converted into sugar thru the action of diastase, has attracted considerable attention as a supplement to skim milk. In experiments covering 3 years with 70 calves Hansen[16] found saccharified starch a cheap substitute for milk fat when fed with skim milk. Calves reared on skim milk and saccharified starch produced cheaper gains than from whole milk, were sleek and thrifty, and developed afterwards in a thoroly satisfactory manner. Feeding more than 0.8 lb. of saccharified starch per head daily leads to scouring. The use of saccharified starch is held to make possible a somewhat earlier change from whole to skim milk. On account of the good results secured with the cereal grains, which are much cheaper, this product is little known in America.

684. Dried blood.—Otis of the Kansas Station[17] found that sickly calves, given at first a teaspoonful and later a tablespoonful of dried blood with their allowance of skim milk, rapidly regained their health. Blood meal which has been especially prepared for calves is best. In all cases it should be carefully incorporated with the milk to prevent settling. **(271)**

685. Mineral matter.—In many cases calves otherwise well nourished suffer from the lack of lime or phosphorus, or both. **(119)** Even tho

[14] Kan. Bul. 126.
[15] La. Bul. 104.
[16] Landw. Jahrb., 37, 1908, Sup. III, p. 235.
[17] Kan. Bul. 126.

milk is high in both lime and phosphorus, Kellner[18] recommends feeding half an ounce of common chalk (carbonate of lime) daily to calves on milk, in view of their rapid growth in skeleton and consequent need of an abundant supply of lime. As hay from the grasses contains a fair amount of lime, and legume hay is rich in this mineral constituent, calves will ordinarily receive enough lime when they are eating hay regularly. In districts where the feeding stuffs are low in lime or phosphorus, or when straw, which is deficient in these mineral nutrients, forms the roughage, either lime alone or both lime and phosphorus should be added to the ration. Gouin and Andouard of France[19] as a result of long continued studies recommend feeding ground bone, such as is used in commercial fertilizers, to calves. Based on the studies with pigs by Hart, McCollum, and Fuller of the Wisconsin Station, it is reasonable to recommend that one-half ounce of ground rock phosphate (floats) be given daily to calves in place of chalk or ground bone.

686. Water and salt.—The calf should be amply supplied with pure fresh water, something which is often neglected with calves fed milk. At the Kansas Station[20] Otis observed that skim-milk calves would drink water several times a day, sipping a little at a time, sometimes soon after their feed of milk. Calves 2 to 3 months old consumed on the average 10 lbs. of water each daily. (**103**)

As soon as the calf begins to eat grain and hay it should be given salt, the same as in the case of older animals. (**101**)

687. Starting the calf on whole milk.—The skim-milk calf is usually allowed to get its milk from the dam for 2 or 3 days, tho many dairymen never allow it to draw milk from the mother, claiming that if separated at once it learns more readily to drink from the pail. In any event the calf should always get the first milk, or colostrum, which is designed by nature for cleansing the bowels and starting the digestive functions. (**115**) If the cow is a heavy milker the calf should not be allowed to gorge on milk lest scours result. After each feeding the cow should be stripped clean. When the cow's udder is caked, leaving the calf with her will aid in reducing the inflammation.

The calf is best taught to drink milk from the pail by using the fingers. If it is allowed to go 12 to 24 hours without feeding, or until it becomes genuinely hungry, much less difficulty will be experienced in the first lesson. Some dairymen use calf feeders, claiming that the slowness with which calves suck milk from the nipple, compared with drinking from the bucket, aids digestion. Hooper found at the Kentucky Station[21] that during the first 7 to 10 weeks calves were more thrifty when fed thru the nipple. After the 70th day, however, the feeder was no more effective than bucket feeding, and by the time the calves were 6 months old there was little difference in size or vigor between the lots. Many of the calf feeding devices on the market are unsatisfactory, and

[18]Ernähr. Landw. Nutztiere, 1907, p. 472.
[19]Expt. Sta. Rec., 19, p. 468.
[20]Kan. Bul. 126.
[21]Ky. Bul. 171.

all are dangerous unless extreme care is exercised in cleansing and sterilizing them.

The young calf has a small stomach and naturally takes milk frequently and in small quantities. Too large an allowance of milk produces indigestion and scours. When milk feéding begins, for the first day or two only 5 to 6 pounds should be fed daily, or somewhat more for a large lusty calf, the allowance being usually divided between 2 feedings. Some advocate feeding at least 3 times a day at first, which occasions little extra work if the cow is milked thrice daily. When the cow is milked twice a day, the bother of warming the milk at noon is held by many not to be repaid. In all cases the milk should be fed as fresh as possible and at blood heat, the temperature being determined by a thermometer, which all careful feeders use. The allowance of milk should be gradually increased, but over-feeding, the common cause of poor success in calf rearing, should be avoided at all times. A safe rule is always to keep the calf a little hungry. Calves should be fed individually, the allowance for each being measured or weighed and the amount fed depending on the size and vigor of the individual. Guernsey and Jersey calves do not require over 8 to 10 lbs. daily for the first 3 to 4 weeks, while 10 to 12 lbs. is all a calf of the larger breeds should have.

688. Feeding skim milk.—When the calf is 2 to 4 weeks old, the exact age depending on its vitality, skim milk may gradually replace the whole milk, the change being usually made at the rate of 0.5 to 1 lb., or slightly more, per day, a week or 10 days being required to get the calf on skim milk alone. With cows giving very rich milk, some prefer to dilute with skim milk from the start. A few breeders feed some whole milk for as long as 2 months.

After the change to skim milk has been made the allowance may be increased very gradually, but should not exceed 18 lbs. daily until the calf is 6 weeks old, and only in rare cases should over 20 lbs. be fed at any time. Skim milk is at its best when, still warm, it goes at once from the farm separator to the calf. Milk held for any length of time or chilled should always be warmed to blood temperature before feeding. In cold weather it is not safe to rely on the skim milk being warm enough as it comes from the separator, but the thermometer should be used. When the calf is 3 to 4 months old it can usually be accustomed to cooler milk provided the temperature is reasonably uniform. The calf pails in which the milk is fed should be kept scrupulously clean, a good rule being to cleanse them as thoroly as the milk pails. Feeding skim milk which is sour, stale, and teeming with undesirable bacteria is a frequent cause of scours. Trials by the United States Department of Agriculture[22] indicate that satisfactory results may be secured in summer with clean milk when soured quickly by lactic acid bacteria, such as are used in starters in butter making. In winter some of the

[22] Breeder's Gazette, 66, 1914, p. 17.

calves showed a distaste for the sour milk. Skim-milk feeding should usually continue for 8 to 10 months, but when the supply of milk is scant a thrifty calf may be weaned after 3 months, provided good substitutes for milk are fed, as shown later. (**697**)

At feeding time hand-reared calves should be confined in stanchions, to remain for a time after the milk is drunk until they consume their concentrate allowance and overcome the desire to suck each other's ears or udders. When this precaution is neglected the shape of the udder may be injured or a heifer may later persist in sucking herself or others.

689. Pasteurizing creamery skim milk.—Patrons of creameries should insist that all skim milk be pasteurized before it is returned to the farm. This precaution keeps the milk sweet and kills the disease-producing bacteria, thereby lessening trouble from scours and preventing the possible introduction of tuberculosis.

In 2 trials at the Ontario Agricultural College[23] Dean found that calves fed pasteurized skim milk (heated to 160° F.) made somewhat better gains than others fed unpasteurized skim milk. At the Kansas Station[24] Otis found practically no difference in the feeding value of pasteurized creamery skim milk and that fed directly from the hand separator, except that the pasteurized skim milk caused less trouble from scouring.

690. Feeding concentrates.—When 1 to 2 weeks old the calf should be taught to eat concentrates. Such feeds as corn meal, sieved ground oats, barley meal, kafir meal, wheat bran, red dog flour, and linseed meal, alone or in mixture, may be placed in the bottom of the pail after the calf has finished drinking its milk. Some add the concentrates to the milk, but this is inadvisable as the meal is then less thoroly mixed with the saliva. The addition of such concentrates as bran or linseed meal to the farm grains may be helpful in teaching the calf to eat. The dull calf may be taught to eat the meal by rubbing a little on its muzzle when it is thru drinking milk. Having learned the taste of the meal, the calf should thereafter be fed its allowance dry from a convenient feed box. Until it becomes accustomed to the new article of diet, a supply of meal may be kept before it. After this, however, only as much should be fed as will be eaten up, and the feed box should be cleaned out regularly. At 6 weeks the calf will usually eat 0.5 lb. of concentrates a day; at 2 months, about 1 lb.; and at 3 months, 2 lbs. Unless it is desired to push the animal ahead rapidly no more than this need be fed the skim-milk calf up to 6 months.[25]

691. Concentrates for skim-milk calves.—The following list by Otis[26] will aid dairymen in selecting feeds for skim milk calves:

[23]Ontario Agr. Col. Rpt. 1899.

[24]Kan. Bul. 126.

[25]Eckles, Dairy Cattle and Milk Production, p. 184.

[26]Wis. Bul. 192.

"1. Corn meal gradually changed in 4 to 6 weeks to shelled corn with or without bran.

"2. Whole oats and bran.

"3. Whole oats and corn chop, the latter gradually replaced by shelled corn in 4 to 6 weeks.

"4. Ground barley with bran or shelled corn.

"5. Shelled corn and ground kafir or sorghum.

"6. Whole oats, ground barley, and bran.

"7. A mixture of 20 lbs. of corn meal, 20 lbs. of oat meal, 20 lbs. of oil meal, 10 lbs. of blood meal, and 5 lbs. of bone meal, changed to corn, oats, and bran when calves are 3 months old.

"8. A mixture of 5 lbs. whole oats, 3 lbs. bran, 1 lb. corn meal, and 1 lb. of linseed meal."

The Guernsey Breeder's Journal,[27] on gathering the experience of over 100 breeders of Guernsey cattle, found that the following were used as supplements to skim milk:

Thirteen fed a mixture of equal parts oats and wheat bran; 11, a mixture of 5 parts oats, 3 parts bran, 1 part linseed meal, and 1 part corn meal; 8, whole oats; 7, ground oats; 7, oats, bran, and linseed meal; 6, corn and oats; 6, the concentrate mixture given the dairy herd; 5, corn meal, oats, and bran; 4, corn meal, bran, and linseed meal; and others, mixtures of wheat middlings and linseed meal, of corn meal and linseed meal, of hominy and bran, and of corn and bran.

The feeder thus has an extended list of successful mixtures from which to select the one most economical for his local conditions.

692. Hay for calves.—Calves will begin to eat hay at about the same age as they do grain, consuming nearly the same quantity of each at first. As the calf grows and its paunch, or first stomach, develops, the proportion of roughage to concentrates should be increased until when 6 months old it will be consuming about 3 times as much hay as grain. The Guernsey Breeder's Journal[28] found in replies from over 100 successful breeders in various parts of the country that the great majority preferred clover or alfalfa hay for calves. Some report better results from bluegrass, native, or mixed hay for the first 2 or 3 months because they are less liable to cause scours. Bright, early-cut hay which is fine and leafy is best for the calf. If legume hay is fed, it may be necessary to restrict the amount lest the calves gorge on this palatable roughage. The heifer should be encouraged to eat a goodly amount of hay to develop the roomy digestive tract desired in the dairy cow. Uneaten portions of the roughage should be removed from the rack or manger before the next feeding time, for calves do not like hay which has been "blown on."

693. Succulent feeds.—A small amount of silage from well-matured corn, free from mold, may be fed to calves when 6 to 8 weeks old. In teaching them to eat this succulence it is well to offer them only the leaves at first. Woll[29] recommends 2 lbs. of silage daily for calves old enough to eat roughage, and 5 to 10 lbs., along with dry roughage, for

[27] Guernsey Breeder's Jour., May, 1915, p. 38.

[28] Guernsey Breeder's Jour., May, 1915, p. 38.

[29] Productive Feeding of Farm Animals, p. 222.

older ones. (**300**) When roots are available they are a most satisfactory succulent feed. (**365**)

Pasture is excellent for calves old enough to make good use of it. To avoid scours they should be turned on grass gradually, say for an hour the first day and for slowly lengthening periods thereafter. Another method is to accustom them to green feed by giving increasing allowances of soilage before turning to pasture. It is well to keep spring or summer calves in their stalls until they are 2 to 4 months old, as there is less trouble from scours, and the young things will not suffer as much from the flies and the heat.

694. Gains of skim-milk calves.—Otis of the Kansas Station[30] gives the following table showing the weight by months of calves reared on skim milk, grain, and pasture from birth until 1 year of age:

Weight of calves from birth until 1 year old

No. of calves	Age	Range in weight	Average weight	No. of calves	Age	Range in weight	Average weight
	Months	Lbs.	Lbs.		Months	Lbs.	Lbs.
23	Birth	59–108	77	38	7	288–461	403
45	1	70–154	111	28	8	332–507	455
56	2	88–199	144	21	9	370–575	515
60	3	111–248	181	20	10	427–645	578
60	4	148–290	229	20	11	444–730	626
54	5	183–362	287	19	12	476–770	669
43	6	228–425	349				

It is shown that calves averaging 77 lbs. each at birth attained an average weight of 669 lbs. at the end of 12 months, showing an average daily gain of 1.6 lbs. for the entire period.

Properly fed on skim milk, along with suitable grains and roughage in liberal supply, the thrifty calf should gain from 1.5 to 2 lbs. daily for the first 4 to 6 months. The aim should be not to fatten the calf but to keep it in a vigorous, growing condition, building strong bone and muscle. Where skim-milk calves do poorly, the blame usually rests with the feeder. The cause of the trouble will ordinarily be found in some one or more of the following conditions: Lack of sunlight and fresh air; unsanitary stalls or boxes that are not properly cleaned and disinfected; feeding too much milk, or at irregular intervals; feeding stale or chilled milk; feeding from pails that have not been scalded daily; feeding improper concentrates or allowing the excess to ferment and stale in the feed box.

II. Raising Calves On Skim-milk Substitutes

Increasing numbers of dairymen thruout the country are selling whole milk for city consumption, for cheese making, or for the manufacture of condensed and evaporated milk. Because it is too expensive

[30] Kan. Bul. 126.

to rear the calves on whole milk alone, many of these men sell the heifer calves from even their best cows for veal and depend upon buying cows to replenish their herds. Since this practice prevents any improvement in their herds, the successful raising of calves on skim-milk substitutes is a question of prime importance.

695. Buttermilk and whey.—Where available, fresh buttermilk is perhaps the best substitute for skim milk, but the watery slop sometimes obtained from creameries, often from filthy tanks, should be avoided, as such material is almost sure to cause scours. At the Kansas Station[31] Otis found that buttermilk gave slightly less returns with calves than skim milk but caused less trouble from scours. (**267**)

The whey usually obtained from the cheese factory, acid and often loaded with germs that derange digestion, is unsuited for calf feeding. Where is it pasteurized and can be obtained sweet and undiluted, whey may give fair results when fed under the strictest rules as to quantity, regularity of feeding, and cleanliness of the vessels employed. Graef[32] secured a daily gain of 2 lbs. with calves fed skim milk, while those getting whey gained from 1 to 1.4 lbs. At the Kansas Station[33] Otis changed calves from skim milk to whey when 3 to 5 weeks old, feeding 10 to 14 lbs. of whey daily with alfalfa hay, prairie hay, kafir meal, and sieved ground oats. The whey-fed calves were thrifty and healthy, tho less fat than those getting skim milk. In feeding whey it should be remembered that instead of being a protein-rich food like skim milk, it is relatively poor in this nutrient. Instead of the cereal grains, feeds high in protein, such as wheat bran and linseed meal, should therefore be fed with it. (**268**)

696. Minimum amount of milk needed by calf.—Fraser and Brand conducted 3 trials with a total of 28 calves at the Illinois Station[34] to determine the minimum total amount of whole milk and skim milk necessary to ensure dairy calves getting a good start before placing them upon concentrates and hay alone. It was found that after the dam's milk was fit for human use calves could be raised successfully on a total of 137 to 167 lbs. of whole milk and 378 to 491 lbs. of skim milk, with good clover hay, and such concentrates as bran, oats, linseed meal, and corn. The calves were fed whole milk for the first 4 days, while the milk could not be used otherwise. Starting with the fifth day, 10 lbs. of whole milk and 2 lbs. of skim milk was fed daily per calf for about 10 days following, after which the whole milk was gradually replaced with skim milk at the rate of 1 lb. per day. Each calf was then fed 12 lbs. of skim milk per day for 20 days, or until 45 days old, when the allowance was reduced 1 lb. each day, no milk being fed after the calves were about 56 days old. The calves were rather thin for a time, but after being kept on pasture with a limited allowance of grain until 6 months old all were in good thrifty condition, and later several developed into good-producing cows.

[31]Kan. Bul. 126. [32]Milchzeitung, 1880, p. 143. [33]Kan. Bul. 126. [34]Ill. Bul. 164.

697. Substitutes for milk.—Several different concentrate mixtures have been used with more or less success as substitutes for milk in calf feeding. While carbonaceous grains are better supplements to skim milk than are concentrates rich in protein, substitutes for milk must supply an abundance of protein, as does milk itself. At the Pennsylvania Station[35] Hayward fed calves whole milk for 7 to 10 days and then gradually substituted a home-mixed calf meal consisting of 30 parts wheat flour, 25 parts cocoanut meal, 20 parts skim-milk powder, 10 parts linseed meal, and 2 parts dried blood, the mixture costing about 3 cents per pound. One pound of the mixed meal was added to 6 lbs. of hot water, and after stirring for a few minutes, cooled to blood heat before feeding. With careful feeding the calves receiving the calf meal made as good growth as others fed skim milk. Hayward points out that calves raised upon a milk substitute should have warm, dry quarters as they are apt to be less resistant to disease than milk-fed calves.

Dean of the Ontario Agricultural College[36] reports success with cocoa-shell milk as a milk substitute. The "milk" was made by boiling one-fourth pound of cocoa shells in 2 gallons of water, and 1.5 to 2 gallons per day was fed with bran, oats, and soilage.

At the North Carolina Station[37] Michels obtained satisfactory results with rolled oats as a substitute for skim milk. Thrifty calves were raised when the allowance of whole milk was decreased to 2 lbs. per head daily by the fifth week, being gradually replaced by a gruel made by adding 12 ounces of rolled oats to 1 gallon of boiling water and allowing the mixture to stand until cool enough to feed. Hooper at the Kentucky Station[38] found calves reared on rolled-oats gruel less vigorous than those fed skim milk.

At the Kansas Station[39] Otis boiled hay, previously soaked in a tank, for 1 or 2 hours. It was then removed and the liquid which remained was concentrated by boiling, 12.5 lbs. of the hay yielding about 100 lbs. of "tea." With kafir meal, wheat middlings, and oil-meal jelly for concentrates the calves fed alfalfa hay tea gained but 0.4 lb. daily, poor returns. On tea from mixed hay calves gained 0.9 lb. daily, making fair growth, but much less than others fed skim milk. Stewart[40] successfully reared 5 calves on hay tea with one-fourth pound each of flaxseed and wheat middlings per head daily. He states that the hay should be cut early, when it has the most soluble matter, and the tea boiled until well concentrated.

At the Indiana Station[41] Caldwell fed 2 lots, each of 10 calves, for 6 months from birth to test the value of a home-mixed calf meal consisting of equal parts of hominy meal, linseed meal, red dog flour, and blood meal, with the following results:

[35] Penn. Bul. 60.
[36] Ontario Dept. Agr., Rpt. 1903, Vol. I.
[37] N. C. Bul. 199.
[38] Ky. Bul. 171.
[39] Kan. Bul. 126.
[40] Feeding Animals, p. 246.
[41] Information to the authors.

Home-mixed calf meal vs. skim milk

Average ration		Wt. at beginning Lbs.	Av. daily gain Lbs.
Lot I			
Calf meal, 1.33 lbs.	Ground oats and corn, 0.84 lb.		
Water, 8.64 lbs.	Alfalfa hay, 2.8 lbs.		
Whole milk, 1.17 lb.	Corn silage, 0.22 lb.	70	0.95
Lot II			
Skim milk, 11.11 lbs.			
Whole milk, 0.72 lb.	Alfalfa hay, 2.5 lbs.		
Ground oats and corn, 0.98 lb.	Corn silage, 0.33 lb.	62	1.21

The calves fed the calf meal, tho making slightly smaller gains than those receiving skim milk, were equally thrifty and vigorous at the close of the trial.

698. Proprietary calf meals.—There are on the market several calf meals, which are more or less complex mixtures of such feeds as linseed meal or flaxseed meal, ground cereals, and wheat by-products, with or without dried milk, casein, and mild drugs. (**285, 289**) These meals are fairly satisfactory substitutes for skim milk, but give no better returns than home-mixed meals that are much less expensive. Dean[42] of the Ontario Agricultural College found ground oats and bran superior to a proprietary calf meal. Savage and Tailby in 2 trials at the New York (Cornell) Station[43] with a total of 37 calves compared 3 proprietary calf meals and skim milk powder with skim milk. The calves fed skim milk made the best gains, closely followed by those fed the skim-milk powder. Those fed the calf meals made fair to good gains, but at a greater expense. Tho in most instances less thrifty at the close of the trial when 5 months of age, by the time they were 2 to 3 years old they had developed into as likely animals as those fed skim milk.

III. General Problems in Rearing Calves

699. Birth weights of dairy calves.—The following table shows the birth weight of dairy calves and the weight of their dams, as determined at the Connecticut (Storrs),[44] Missouri,[45] and Wisconsin Stations:[46]

Birth weight of calves of the dairy breeds

Breed	Number of calves	Av. wt. of males Lbs.	Av. wt. of females Lbs.	Average of both sexes Av. wt. of calf Lbs.	Average of both sexes Wt. of dam Lbs.	Wt. of calf to wt. of dam Per ct.
Jersey	119	58	49	55	900	6.11
Guernsey	57	75	68	71	996	7.13
Ayrshire	34	77	74	76	976	7.79
Holstein	104	94	85	89	1,153	7.72
Brown Swiss	5	107	90	100	1,123	8.90
Dairy Shorthorn	8	...	..	76	1,249	6.08

[42] Ontario Agr. Col. Rpts. 1900, 1905.
[43] N. Y. (Cornell) Buls. 269, 304.
[44] Beach, Conn. (Storrs) Rpt. 1907.
[45] Eckles, Dairy Cattle and Milk Production, p. 174.
[46] Unpublished data compiled by the authors.

The table shows that in each breed the bull calves average heavier than the heifers. The weights of the Jersey calves at the Wisconsin Station ranged from 44 to 80 lbs.; of the Guernseys, from 48 to 87 lbs.; of the Ayrshires, from 62 to 89; and of the Holsteins, from 62 to 108. Calves from mature cows are generally somewhat heavier at birth than from heifers.

700. Economy of gains by calves.—Linfield of the Utah Station[47] found that up to 14 weeks of age the calf takes less dry matter than the pig for 1 lb. of gain, and after that more, because of the greater amount of roughage then used in the ration. Beach of the Connecticut (Storrs) Station[48] found that calves required 1.03; lambs 1.08; and pigs 1.36 lbs. of dry matter in whole milk for each pound of gain made. Martiny[49] found that from 3.5 to 6 lbs. of new milk was sufficient to produce a pound of gain, live weight, with calves between the first and fifth weeks, while older ones required from 16 to 20 lbs.

At the Pennsylvania Station[50] Hunt fed 3 calves whole milk containing 4.6 per ct. of fat for 161 days. They gained 1.77 lbs. each daily, requiring 8.8 lbs. of whole milk and 1 lb. each of hay and grain for a pound of gain.

701. Feed required by the calf.—The following table shows the total amount of feed required by skim-milk calves up to 6 months of age, as determined by Beach at the Connecticut (Storrs) Station[51] and by Eckles at the Missouri Station:[52]

Feed required by skim-milk calves to 6 months of age

Station	No. of calves	Wt. at beginning	Average daily gain	Whole milk	Skim milk	Concentrates	Hay	Pasture
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Days
Connecticut								
Fed whole milk 4 weeks	8	65	1.31	220	2,908	...	619	..
Fed whole milk 2 weeks	9	59	1.25	90	3,001	127	337	..
Missouri								
Spring calves	4	74	1.42	367	3,041	90	80	90
Fall calves	3	51	1.10	367	2,331	159	275	..

From these data the cost of feed for a calf up to 6 months of age may be readily computed at market prices.

702. Fall calves.—Where cattle are reared under natural conditions, the rule that the young be dropped in the spring will continue, but this practice is not necessarily the most successful in the older sections of the country. Fall-dropped calves come at a time when the little attentions they need can easily be given, and they occupy but little space in barn or shed. Subsisting on the mother's milk, or on skim milk with a little grain and hay, when spring comes the youngsters are old enough to make good use of the pastures and to stand the hot weather and the attacks of flies and mosquitoes.

[47] Utah Bul. 57.
[48] Conn. (Storrs) Rpt. 1904, p. 118.
[49] Die Milch, 2, 1871, pp. 9–15.
[50] Penn. Rpt. 1891.
[51] Conn. (Storrs) Rpt. 1903.
[52] Dairy Cattle and Milk Production, p. 180.

703. Scours.—The most frequent trouble in raising calves by hand is indigestion, or common scours. This is usually caused by over-feeding, by the use of cold milk or that laden with disease germs, by dirty pails or feed boxes, or by keeping calves in dark, dirty, poorly-ventilated stalls. Each animal should be watched closely for signs of scours, for a severe case gives the calf a setback from which it recovers but slowly. Since soft, foul-smelling dung is often the first indication of trouble, it is well to keep each new-born calf in a pen by itself for 2 to 3 weeks where it can be observed more closely than if it ran with others. At the first indication of scours the ration should be reduced to less than half the usual amount. Such remedies as castor oil, formalin, and a mixture of salol and bismuth subnitrate, are used with success by dairymen.

Common scours should be distinguished from contagious, or white, scours, also called calf cholera, which is due to an infection of the navel soon after birth. This most serious disease, from which an animal once affected rarely recovers, may usually be avoided by providing that the calf be dropped in a clean stall or on pasture. When the calf is born in the barn, it is best to wet the navel thoroly with a disinfectant, such as a weak solution of creoline, zenoleum, or bichloride of mercury.

IV. The Heifer

The rearing of the heifer after 6 to 8 months of age is an easy task, and perhaps because of this many are stunted for lack of suitable feed. Since the usefulness of the cow when mature is dependent on her proper development before the first calf is dropped, it is important to heed the few essentials in feeding and caring for the heifer.

704. Feeding the heifer.—Heifers on good pasture usually require no additional feed. In winter there is no better ration than legume hay, silage, and sufficient grain to keep them thrifty and growing without becoming fat. The ration should supply an abundance of protein and mineral matter, and hence unless legume hay forms the roughage, the concentrate allowance should be more nitrogenous in character than advised for skim-milk calves. From 2 to 3 lbs. of concentrates with 8 to 10 lbs. of legume hay and 12 to 20 lbs. of silage, or 12 to 15 lbs. of legume hay, alone, if no silage is available, should be provided for the ration during the second year.

Many breeders hold that if the heifer is allowed to become fat she will develop a tendency toward using her feed for the formation of body fat, which will persist when she is in milk. Eckles states that in trials at the Missouri Station[53] in which heifers were variously fed before calving, heavy feeding while young had no injurious effect on the productive capacity of the animals when mature. Heifers which were kept fat from birth until calving lost the surplus body fat within a short

[53]Dairy Cattle and Milk Production, p. 206.

time thereafter and showed no more tendency to fatten later on in the lactation period than those raised on a less abundant allowance of concentrates. The most marked effect of heavy feeding of concentrates was a more rapid growth and quicker maturity. The results show, however, that feeding a heavy allowance of concentrates is a much more expensive way of raising heifers than giving them a ration consisting mostly of good roughage.

705. Age to breed.—The age at which heifers should drop their first calves depends on the breed and the size and development of the individual. Jerseys and Guernseys which have been well-fed are usually bred to calve at 24 to 30 months of age, while the slower maturing Holsteins, Ayrshires, or Brown Swiss should not calve until 30 to 36 months old. Some breeders believe that if the heifer calves at an early age, the tendency to milk production will be intensified. Owing to the demands of the fetus, the heifer makes but little growth in her own body during the last few months before calving, even when liberally fed. Where early calving is practiced, breeders therefore usually allow 18 to 20 months to elapse between the first and second calves in order to give the heifer an opportunity to continue her growth. Further, it is believed that lengthening the first lactation period tends to make the heifer a more persistent milker. As a rule cows that have dropped their first calves at an early age are finer in bone and often considerably smaller than those which do not calve until more mature.

706. Feed eaten by heifers; cost of rearing.—The following table shows the total amount of feed eaten by heifers during the first and second years, as determined in trials by Trueman at the Connecticut (Storrs) Station[54] with 5 head, by Bennett and Cooper of the United States Department of Agriculture[55] with 17 to 20 heifers on a Wisconsin farm, and by Shaw and Norton at the Michigan Station[56] with 57 calves:

Feed eaten by heifers up to 2 yrs. of age

	Connecticut	Wisconsin	Michigan
First year			
Whole milk, lbs	445	342	405
Skim milk, lbs	2,953	3,165	3,968
Concentrates, lbs	303	547	1,144
Hay, lbs	918	857	1,007
Silage, roots, or soilage, lbs	1,245	353	1,354
Pasture, days	135	123	....
Second year			
Concentrates, lbs	434	.....	....
Hay or other dry fodder, lbs	2,227	1,792	....
Silage, lbs	1,693	3,250	....
Pasture, days	165	171	....

In the Connecticut trial the heifers were fed a limited allowance of concentrates during their second year, while in the Wisconsin test they were fed only hay and silage during the winter and grazed on pasture without additional feed in the summer. In the Michigan test the calves

[54] Conn. (Storrs) Bul. 63. [55] U. S. Dept. Agr. Bul. 49. [56] Mich Bul. 257.

were not turned to pasture during the summer and were fed a heavier allowance of grain than is usual thruout the year.

Trueman estimates the cost of rearing a heifer to 2 years of age in Connecticut as follows: Cost of feed, first year, \$28.34; cost of feed, second year, \$27.25; labor for both years, \$10.00; bedding for both years, \$2.00; barn rent, insurance, and taxes, \$4.00; total gross cost, \$71.59; credit for manure, \$5.00; net cost for two years \$66.59.

From records for 117 calves Bennett and Cooper found that the cost of rearing dairy heifers born in the fall was as follows:

Cost of rearing dairy heifers in Wisconsin

	Cost to 1 year Dollars	Cost to 2 years Dollars
Initial value of calf	7.04	7.04
Feed	24.67	40.83
Labor	4.45	7.81
Other costs	6.36	13.73
Gross cost	42.52	69.41
Credit for manure	3.00	8.00
Net cost	39.52	61.41

Under "other costs" are included charges for barn equipment and utensils, interest, bedding, losses by death and from discarding poor individuals, share of general overhead expense in running farm, and miscellaneous expenses. Many of these items are not ordinarily taken into consideration by the dairyman in estimating how much it costs him to raise heifers. Labor, both man and horse, is charged at a uniform figure thruout the year. It should be remembered that with fall calves most of the labor comes in the winter when farm work is light and labor worth much less than in summer. The cost of raising heifers will naturally vary widely in different districts depending on prices for feed and labor, the shelter required, etc.

V. The Bull

Despite the fact that improvement in the productive capacity of the dairy herd rests as much with the bull as with the cows, the feed and care of the sire at the head of the herd is often neglected. To build up a profitable herd a pure-bred bull which has been bred for dairy production should be selected; this done, he should be so fed as to keep in the best condition for breeding.

707. The young bull.—The same principles apply to the rearing of the bull calf as to the heifer. The bull should be fed from birth to maturity so as to make normal growth, for, while the offspring of an animal which is thrifty but is undersized on account of insufficient feed will not necessarily be smaller than those from a larger sire, such an animal will bring a lower price when it is desired to sell him to another dairyman. From 6 months of age, when the bull calves should be separated from the heifers, they should be fed a somewhat heavier allowance of grain. The bull should be sufficiently mature for very light service at 10 to 12 months of age. He should be halter broken as a calf and when about 1 year old should have a stout ring inserted in his nose. He should be so handled from calfhood that he will recognize man as his master and should never be given an opportunity to learn his great strength. Stall and fences should always be so strongly built that there is no possibility of his learning how to break loose.

708. Feed and care of the bull.—The ration for the bull in full service should be about the same as for a dairy cow in milk. He should be given good legume hay or hay from mixed legumes and grasses and fed from 4 to 8 lbs. of concentrates, supplying an ample amount of protein. When idle or but in partial service less concentrates will be required. Some breeders hold that feeding corn silage impairs the bull's breeding powers and therefore prefer roots. Hoard's Dairyman,[57] holds that a bull may be fed 10 to 15 lbs. of silage per day with satisfactory results in a properly balanced ration.

Except in severe climates the best quarters for the bull are an open shed with an adjoining paddock where he may exercise. Tho this open-air treatment is admirable for the health of the animal, it results in a heavier and rougher coat of hair, and hence breeders offering animals for sale usually prefer to keep the bulls in comfortable box stalls, turning them out only on fair days. Rather than confine the bull in isolation, it is well to have his stall so located and built that he can see the other members of the herd. The hoofs of the bull spending most of his time in the stall need regular trimming. The bull should be tied by a strong halter to one end of the manger and by his ring to the other end, so that the attendant may approach him from either side without danger. The bull should be dehorned and should always be handled with a strong, safe staff. Even with a quiet, peaceable bull safety lies only in handling him without displaying fear and yet as if he were watching for an opportunity to gore his attendant. Nearly all the accidents occur with "quiet" bulls that have been too much trusted.

To maintain health and virility, the bull must have ample exercise. This is perhaps most conveniently furnished by a tread power, where he may run the separator, pump water, do other useful work, or run the power for exercise only. Many declare that the purchase of a tread power merely to furnish exercise for the bull is a wise investment. Others fix a long sweep on a post and tie the bull at the end, allowing him to walk around the circle. Another device is a light cable stretched between 2 high posts, the bull being attached to it by a sliding chain so that he is able to walk back and forth the length of the cable. The bull may also be harnessed and hitched to cart or wagon for such odd jobs as hauling manure or feed. Whatever the plan adopted, it is essential that the bull receive ample and regular exercise, else he is almost certain to develop an ugly disposition and may become impotent.

[57] Hoard's Dairyman, 46, 1914, p. 339.

CHAPTER XXVI

GENERAL PROBLEMS IN BEEF PRODUCTION

During recent years the number of beef cattle in the United States has decreased, rather than increased, while our population has been growing rapidly. Hence we find that the number of beef cattle per thousand people has fallen off markedly. In 1900 there were about 660 cattle, other than milch cows, per 1,000 inhabitants in this country, but in 1910 the number had decreased to 450, and later estimates indicate a further failure of beef cattle to keep pace with population. Among the reasons for this condition are the breaking up of large areas of the western ranges into farms, the high prices ruling for grain and the consequent tendency of many farmers to sell their crops for cash rather than feed them to stock, the increase in the number of tenant farmers who have insufficient capital to stock their farms, the growth in dairying due to the demand from the rapidly growing cities for dairy products, and the fact that not infrequently the fattened steer has been grown or finished at a loss.

Beef production has naturally become separated to a considerable extent into 2 distinct phases. In sections where the land is unsuited for tillage, either by reason of its rough nature or deficient rainfall, breeding herds are maintained and cattle raised to be sold as feeder steers. On the other hand, in the corn belt, where land is high in price, the majority of the steers which are fattened for market are not raised by the men who finish them, but are shipped in from the range districts. Altho many steers are still fed by farmers who handle only a few head each year, the fattening of cattle has passed to a considerable extent into the hands of professional feeders, who fatten from a few carloads to hundreds of animals yearly. In many instances these men make but little use of the manure produced and purchase most of their feed. On such a basis the enterprise is largely speculative.

Fortunately for the American public, which would be exceedingly loath to give up beef as a common article of diet, our experiment stations have pointed out the manner in which the cost of beef production may be brought down to where it yields a reasonable profit to the farmer without the finished product being unduly costly to the consumer. The trials reviewed in these chapters show how the breeding herd may be maintained cheaply, utilizing the roughage which would otherwise be wasted on the farm, and the steer finished for market on a much smaller allowance of concentrates than was formerly believed to be necessary. The next few years should see beef breeding herds established on thousands of farms in the corn belt, where the maximum use will be made of corn silage and only limited pasture be employed, in the eastern states, with their low-priced grazing land, and in the South, with its tremendous possibilities for beef production, especially where the cattle tick has been eradicated. These farmers will look for their profits largely in the increased fertility which will come to their fields and in the profitable utilization of roughages which would otherwise be wasted. As is explained in Chapter XXIX, the general methods followed will be adapted to the local conditions in each region.

I. Influence of Age; Long and Short Feed

709. Margin.—Under usual conditions, the cost of the feed consumed by fattening cattle or sheep per 100 lbs. of gain is greater than the selling price per cwt. of the finished animal. With normal market conditions, this is offset by the fact that fattened animals usually sell for a higher price per 100 lbs. than feeders, which are animals in thinner flesh. This difference between the cost per cwt. of the feeder and the selling price per cwt. of the same animal when finished is called the *margin.* In studying all commercial aspects of the fattening of meat-producing animals a clear understanding of this term is most essential.

The principle of the margin may be illustrated thus: If a 1000-lb. steer costs the feeder $7.00 per cwt. when placed in the feed lot, its initial cost is $70.00. If during fattening it gains 400 lbs. at a feed cost of $36.00, each cwt. of gain costs $9.00. Assuming that the manure produced pays for the labor, the steer, now weighing 1,400 lbs., has cost $106.00 and accordingly must bring $7.57 per cwt. at the feed lot to even the transaction. On account of the high cost of the gains, under all usual conditions a margin must be secured in fattening cattle or sheep to make a profit or "break even" on the transaction. The term *necessary margin* is used to denote the margin needed to prevent loss. In this case it will be $0.57, the difference between $7.57 and $7.00. The *actual margin* is the difference between the actual selling price and the purchase price.

The factors which influence the necessary margin in fattening are: 1, the initial cost of the cattle; 2, their initial weight; 3, the cost of the gains; and 4, the expenses incidental to getting the steers to the feed lot and then to the market when finished.

Other conditions remaining the same, the higher the initial cost, or purchase price, of the feeder the narrower, or smaller, is the necessary margin. For example, let us assume that a feeder steer weighing 1,000 lbs. is fed until he has reached a weight of 1,300 lbs., the gain costing 10 cents per pound for feed. If the feeder costs $4.00 per cwt., he will have to bring $70.00, or $5.38 per cwt., to break even. The necessary margin would then be $5.38-$4.00=$1.38. Had the feeder been bought for $7.00 per cwt., no money would be lost if he were sold for $100.00, or $7.69 per cwt. In this case the necessary margin would be only $0.69.

The heavier the animal when placed on feed the narrower will be the necessary margin, for the increased selling price is secured for a greater number of pounds of initial weight. This factor may be offset, as is shown later, if the heavier cattle are older and hence make more expensive gains.

It is evident that any factor which increases the feed cost of the gains makes necessary a wider margin. The necessary margin is thus greater when feeds are high in price, and is wider with mature animals than with younger ones, which make more economical gains. (**710-13**) Since gains on grass are usually cheaper than in the dry lot, a wider margin is required for winter feeding than in fattening animals on pasture. (**814**) The higher the degree of finish, or fatness, to which the animals are fed, the more expensive the gains become and the wider the necessary margin. (**714**)

From statistics gathered from feeders in Missouri, Iowa, and Illinois in 1902, Waters[1] found that an average margin of $1.02 was required to cover the entire cost of fattening cattle in summer—that is, they must sell for $1.02 per cwt. above the purchase price to break even on cost of production. For the 6 months of winter feeding with 2-yr.-olds, Waters held that a margin of $1.50 per cwt. was necessary. Skinner and Cochel of the Indiana Station[2] found in 1906 that with Indiana cattlemen it cost $4.80 per cwt. for summer gains and $7.20 per cwt. for winter gains, and that an average margin of $1.07 per cwt., or 20 cents per cwt. per month, was required. Conditions have changed materially since these dates. Any one can readily compute the approximate margin required under his local conditions from the cost of feeders, the price of the available feeding stuffs, and the amount of feed required for 100 lbs. gain.

710. Feed and gains from birth.—To determine the amount of feed consumed by a steer from birth to maturity and the feed-cost of gains in successive periods of its growth, Zavitz[3] of the Ontario Agricultural College confined an animal from 3 days of age until 3 years old in a well-bedded box stall, giving exercise, when required, by leading. Account was kept of all water and food supplied, and of the voidings, as shown in the table:

Feed and gains by steer from birth to maturity

	First year	Second year	Third year
	Lbs.	Lbs.	Lbs.
Daily gain	2.2	1.2	1.0
Total gain	785	456	350
Feed per 100 lbs. gain			
Milk	492	......	......
Concentrates	159	480	689
Hay	184	777	776
Succulent feed	314	1,928	2,637
Digestible nutrients per 100 lbs. gain	315	875	1,183
Water drank daily	27	43	47
Excrement voided daily	30	48	50

[1] Mo. Bul. 76. [2] Ind. Cir. 12. [3] Ont. Agr. Col. Rpt. 1893.

During the first year the steer gained 2.2 lbs. per day, or a total of 785 lbs., while the daily gain for the second year was only 1.2 lbs. and for the third year but 1.0 lb. In the first year there were required on the average for 100 lbs. gain 492 lbs. of milk, 159 lbs. of concentrates, 184 lbs. of hay and 314 lbs. of succulent feed (roots, silage, or green fodder), containing a total of only 315 lbs. digestible nutrients. The second year nearly 3 times and the third year nearly 4 times as much digestible nutrients were required for the same amount of gain. A small part of this difference is accounted for by the fact that the flesh of the calf is more watery and contains less nutrients per pound than that of the older animal. **(123)** The average amount of water consumed and of excrement voided is shown in the last lines of the table.

At the end of the 3 years the steer weighed 1,588 lbs. and would have yielded about 1,000 lbs. of dressed carcass. During this time it had consumed a total of 3,862 lbs. of milk (in the first 6 months), 5,857 lbs. of concentrates, 7,716 lbs. of hay, and 20,511 lbs. of succulent feed. Accordingly, for each pound of meat as sold by the butcher there were required about 3.9 lbs. of milk, 5.9 lbs. of concentrates, 7.7 lbs. of hay and 20.5 lbs. of succulent feed. When we realize that there are many other items of expense besides the mere cost of the feed consumed by the steer, it is evident that the price which the producer gets for the live steer is less rather than more than it should be. It is doubtful if any other article of universal use and necessity is continuously sold on so narrow a margin over cost, if any, as the live fattened steer.

711. Influence of age on cost of fattening.—At the Ottawa Experimental Farms[4] in trials during 4 winters with 153 head in all, Grisdale compared the rate and cost of gains made by steers of different ages during feeding periods of about 6 months. The results are shown in the following table, partially as arranged by Waters.[5]

Rate and cost of gains for fattening steers of various ages

	Av. wt. at beginning	Av. daily gain	Av. cost of 100 lbs. gain	For equal profit compared with calves	
				Purchase price per cwt. must be less by:	Or selling price per cwt. must be greater by:
	Lbs.	Lbs.	Dollars	Cents	Cents
Calves*	397	1.8	4.22	..	..
Yearlings	883	1.6	5.31	35	27
2-yr.-olds	1,011	1.8	5.62	43	33
3-yr.-olds	1,226	1.7	6.36	53	43

*Three trials.

It is seen that 6-months calves averaging 397 lbs. in weight made an average daily gain of 1.8 lbs. during the fattening period of about 6 months, yearlings to 3-yr.-olds averaging about the same. The feed cost for 100 lbs. of gain was $4.22 with the calves, and increased with the age of the animals, the gains made by the 3-yr.-olds costing $6.36, or 50 per ct. more than the calves, for each 100 lbs.

[4]Ottawa Expt. Farms Rpts. 1900-1904. [5]Mo. Bd. Agr. Rpt. 1907.

The greater cost of the gain by the older animals might have been offset by buying these steers as feeders at slightly lower prices per 100 lbs. than the younger animals, or by a small increase in their selling price when fattened, because of their superior condition. Had the yearlings been purchased for 35 cents per 100 lbs. less than was paid for the calves and sold at the same price per 100 lbs., or if after fattening they had been sold for 27 cents more per 100 lbs., the increased cost of the gains by the yearlings would have been met.

712. Fattening calves, yearlings, and 2-yr.-olds.—During each of 3 winters, Skinner and Cochel fed 1 lot of ten 2-yr.-old steers, 1 of 10 yearlings, and another of 20 calves at the Indiana Station[6] to determine the influence of age on the economy of gains and the profit from feeding cattle. The calves were of the best type and breeding possible to obtain, as it is not practicable to attempt to produce fine yearling beef from inferior calves. The yearlings and 2-yr.-olds compared favorably with the calves in capacity and condition at the beginning of each test, though not of quite so good type. Each lot was fed until all would sell as prime beeves. The following table, in which the results for 2 winters in which the same feeds were used are averaged, shows that the time required to make the steers fat was greater with the younger animals because the older ones had more nearly reached their limit in growth:

Fattening calves, yearlings, and 2-yr.-olds

	Calves	Yearlings	2-yr-olds
Number of cattle	20	10	10
Initial value per cwt	$4.50	$4.15	$4.12
Av. initial weight, lbs	518	888	1,067
Length of feeding period, months	9	6.5	6
Av. daily gain, lbs	1.88	2.22	2.6
Av. total gain, lbs	508	431	471
Av. feed consumed per head:			
Shelled corn, lbs	3,026	3,034	3,212
Cottonseed meal, lbs	445	480	510
Clover hay, lbs	857	714	760
Corn silage, lbs	1,950	2,849	2,700
Feed per 100 lbs. gain by steers:			
Shelled corn, lbs	596	704	681
Cottonseed meal, lbs	88	111	108
Clover hay, lbs	168	165	160
Corn silage, lbs	385	660	573
Feed cost per 100 lbs. gain*	$7.74	$9.09	$9.37
Selling value per cwt with prices during trial stationary*	$6.60	$6.45	$6.35
Profit per head with stationary prices*	$4.25	$6.43	$7.95
Pork per bushel of corn fed to steers, lbs*	1.00	1.85	2.50

*Av. of 3 trials.

As is usual, the calves cost more per 100 lbs. live weight than did the older feeders. The rate of daily gain increased with the age of the steers, yet the older ones required more feed per 100 lbs. gain than did the calves, thus making their gains more expensive. The calves ate less feed

[6] Ind. Bul. 146.

per head daily, but required a longer time to finish, and so there was little difference in the amount of feed required to make the steers of the various ages prime. Skinner and Cochel state that with quality, breeding, and type the same, calves, yearlings, and 2-yr.-olds will sell at about the same price per 100 lbs. if equally fat. From the 3 trials they conclude that the average margin required between buying and selling prices to prevent loss was $1.60 per cwt. on calves, $1.71 on yearlings, and $1.55 on 2-yr.-olds. The smaller necessary margin with the 2-yr.-olds was due to their greater initial weight and the smaller gains necessary to finish them. These two factors more than offset the cheaper gains made by the calves and their higher cost per 100 lbs. With the yearlings, the differences in the initial weight and in the amount of gain required for finishing were not sufficient to overcome the advantage due to the cheaper gains and greater cost of the calves. Hence a larger necessary margin was required with the yearlings than with the calves. Based on stationary market prices thruout the trial, the profit per head increased with the age of the animals fed. Skinner and Cochel conclude that the experienced farmer who buys feeders and finishes them for the market should handle older cattle in preference to calves, while one who both raises and finishes his cattle may find calves more profitable. The table shows an added advantage with the older cattle in the amount of pork produced by the pigs following the cattle, per bushel of corn fed the steers. In similar trials at the South Dakota Station[7] Wilson found with 2- and 3-yr.-old steers that 1 lb. of pork was made for every 5 lbs. of beef produced, while with yearlings only 1 lb. was made for every 9 lbs. of beef.

In a survey of the cattle feeding industry in Indiana, Skinner and Cochel[8] found that of 929 feeders, 76 per ct. fed 2-yr.-olds, 16 per ct. yearlings, and only 7 per ct. calves. The average weight desired in a 2-yr.-old was 1,000 lbs. Some feeders preferred steers 3 years old or over, the reason being that such cattle usually carry more flesh and make more rapid gains, thus requiring a shorter feeding period. They also need less grain to finish them, utilize coarser food, feed out more uniformly, and withstand severe weather better.

713. Utilization of feed by range steers.—Under southwestern range conditions the calves, dropped in the spring or summer, run with the cows until weaned in the fall, normally making good growth during this period. About weaning time the ranges dry up, and the calves must subsist on scanty pickings with usually a small allowance of concentrates, generally cottonseed cake or meal. Hence, before the calves are a year old they will have passed thru a semi-starvation or sub-maintenance period, and this will occur each year of the steer's life. To determine whether these periods had any permanent effect on the animal's ability to utilize feed, and to study the efficiency of steers of different ages, Christensen and Simpson of the New Mexico Station[9] conducted trials

[7] S. D. Bul. 125. [8] Ind. Cir. 12. [9] N. Mex. Bul. 91.

lasting 120 days with range steers,—calves, yearlings, 2-yr.-olds, and 3-yr.-olds—all fed alfalfa hay alone, securing the results shown in the table:

Utilization of alfalfa hay by range steers of different ages

	Av. ration per 1,000 lbs. live wt. Lbs.	Av. daily gain Lbs.	Dry matter digested Per ct.	Hay per 100 lbs. gain Lbs.
Calves	24.4	1.67	56.6	777
Yearlings	23.3	1.33	55.2	1,111
2-yr.-olds	23.5	1.55	57.1	1,146
3-yr.-olds	18.4	1.03	57.1	2,034

The calves made the largest gains and the 3-yr.-olds decidedly the lowest, but this was undoubtedly due to the fact that they were wilder and more nervous. There were no consistent differences in the ability of the steers of the various ages to digest the hay, the variations in the different periods and between the different animals of the same age being greater than between the different ages. The calves, however, consumed much less hay per 100 lbs. gain, as we would expect, since the flesh of calves is more watery, contains less fat, and hence has a lower energy value than the increase of more mature animals. **(123)**

714. Influence of degree of finish.—Other conditions being equal, the higher the degree of finish to which the animal is carried the larger the quantity of feed required to produce a given gain. Georgeson of the Kansas Station[10] found the grain required for 100 lbs. of gain with fattening steers for different periods to be as follows:

	Grain for 100 lbs. gain	Increase of feed required
Up to 56 days the steers required	730 pounds of grain	....
Up to 84 days the steers required	807 pounds of grain	10 per cent
Up to 112 days the steers required	840 pounds of grain	15 per cent
Up to 140 days the steers required	901 pounds of grain	23 per cent
Up to 168 days the steers required	927 pounds of grain	27 per cent
Up to 182 days the steers required	1,000 pounds of grain	37 per cent

We learn that while at first only 730 lbs. of grain were required per 100 lbs. of gain, for the whole 6-months period 1,000 lbs., or 37 per ct. more, was required. The heavy cost of thoroly fattening the steer and the importance of selling at the earliest possible date are here made plain. In a trial at the Illinois Station[11] with 96 steers fed for 179 days, following a limited allowance of grain for 3 weeks, Mumford found that less digestible nutrients were required for 100 lbs. gain during the last half than in the first half of the fattening period. He points out that with these steers the "fill" was eliminated, which often makes the gains during the first part of the period appear large and economical. As these steers were sufficiently finished to meet the high demands of the Chicago market, of good type and all grading good to prime, he concludes that it is unnecessary to carry steers to that degree of fatness which necessitates small gains for food consumed.

[10]Kan. Bul. 34. [11]Ill. Bul. 90.

715. Short vs. long feed.—Two distinct methods are followed in fattening steers in dry lots. In "short feeding," mature, fleshy feeders are usually given a heavy grain feed for 90 to 100 days or less. In "long feeding" younger or lighter and thinner cattle are fed for a longer period. To determine the relative profitableness of these methods, during each of 4 winters Skinner and Cochel short-fed one lot of steers for 90 to 120 days at the Indiana Station[12] while another lot was long-fed for 160 to 180 days, with the results shown in the table:

Short vs. long feeding periods

	Lot I Short-fed	Lot II Long-fed
Av. length of feeding period, days	110	175
Total number of steers	50	40
Av. weight at beginning, lbs	1,165	1,000
Av. gain per head, lbs	307	431
Av. daily gain, lbs	2.81	2.46
Av. ration:		
Shelled corn, lbs	19.72	16.66
Cottonseed meal, lbs	2.96	2.78
Clover hay, lbs	4.41	4.48
Corn silage, lbs	15.33	14.42
Feed per 100 lbs. gain:		
Shelled corn, lbs	702	678
Cottonseed meal, lbs	106	114
Clover hay, lbs	152	183
Corn silage, lbs	558	584
Feed cost of 100 lbs. gain	$9.03	$9.34
Initial cost of steers per 100 lbs	$4.69	$4.36
Necessary margin	$1.03	$1.61
Necessary selling price	$5.72	$5.97
Actual selling price	$6.31	$6.64
Profit per steer, including pork	$15.27	$16.41

Lot I, the short-fed steers, which were given the heavier and more concentrated ration, made larger gains and at a less feed-cost per 100 lbs. gain. Due to the fact that they were in better flesh, the initial cost of the steers in Lot I was 33 cents per 100 lbs. more than those in Lot II. On account of this and of their heavier initial weight, the smaller amount of gain needed to finish them, and their cheaper gains, they could have been sold without loss on a narrower margin than the long-fed steers. This brought the necessary selling price of Lot I 25 cents per 100 lbs. lower than that of Lot II. The long-fed steers, however, brought enough more when sold to more than counter-balance this advantage, and hence returned a slightly larger profit, when the pork produced by hogs following was included.

The kind of cattle to be fed should largely determine the length of feeding period, since a longer time is required to finish young or thin cattle than those which are fleshier or more mature. Another determin-

[12]Ind. Buls. 130, 136, 153.

ing factor should be the relative supply and cost of grain and roughage, for short-fed cattle, which are usually in higher condition when placed on feed, should be given a larger proportion of grain to roughage than is needed with long-fed cattle.

716. Feeding steers chiefly on roughage in early part of fattening period.—During each of 3 years Skinner and King[13] fed 1 lot of steers clover hay and corn silage during the first 60 to 70 days of the fattening period, with 2.5 lbs. of cottonseed meal per 1,000 lbs. live weight in addition, in 2 of the trials. The steers were then finished on the same feeds with all the shelled corn they would eat. A second lot was fed an unlimited allowance of corn from the start, the results being shown in the following table:

Limiting concentrates during early part of fattening period

	Initial weight	Daily gain	Feed per 100 lbs. gain			Feed cost of 100 lbs. gain	Necessary margin
			Concentrates	Hay or straw	Corn silage		
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Dols.	Dols.
Lot I, no corn at first Shelled corn, 9.0 lbs. Cottonseed meal, 2.4 lbs. Hay or straw, 3.6 lbs. Corn silage, 35.2 lbs.....	1,013	2.15	529	170	1,637	8.71	0.72
Lot II, corn thruout trials Shelled corn, 14.0 lbs. Cottonseed meal, 2.8 lbs. Hay or straw, 2.5 lbs. Corn silage, 27.5 lbs.....	972	2.41	697	103	1,143	8.87	0.87

Lot I, fed no corn during the first 2 months of the fattening period, made smaller gains than Lot II, fed corn thruout the trials, and required more roughage but less concentrates per 100 lbs. gain. The relative feed cost of the gain under these systems of feeding will depend on the cost of concentrates compared with roughage. In these trials the cost averaged slightly lower for steers in Lot I. Owing to the slightly cheaper gains, the necessary margin was somewhat lower with Lot I. The steers in this lot, however, sold at a lower price each year on account of inferior finish, and returned less profit than those in Lot II.

Feeding roughage alone or with only a small allowance of concentrates during the early part of the feeding period is often advisable when it is desired to carry the steers longer than usual before marketing, with the hope of a better price. They will then not become excessively fat and hence will not make uneconomical gains before they are marketed.

In a trial at the Pennsylvania Station[14] Cochel fed a lot of twelve 880-lb. steers only corn silage and 2.5 lbs. of cottonseed meal daily per 1,000 lbs. live weight for the first 56 days of a 126-day trial and ear corn in addition thereafter. Another lot was given the same feeds with ear

[13] Ind. Buls. 153, 163, 167. [14] Penn. Bul. 118.

corn from the start. The steers fed no corn during the first part of the period made as large gains as the others and returned a larger profit, tho selling for 20 cents less per 100 lbs. In a later trial at the same Station[15] Tomhave and Severson found that it was preferable to begin feeding a small amount of corn after the first month of the fattening period owing to the better finish thus secured.

II. Value of Breed in Beef Making

Everyone with experience in the cattle business knows that "blood tells" in beef production. Where there is such unanimity of opinion the fact must exist, but the reasons given are not always the same. Let us, therefore, consider the trials conducted by the various stations which bear on this important point.

717. Fattening steers of the various market grades.—To determine the rapidity and economy of gains made by feeders of the 6 different market grades and the dressing percentages and the quality of the beef from the steers when fattened, Mumford fed 16 steers of each grade at the Illinois Station[16] for 179 days. Lot I, fancy selected feeders, contained nearly 100 per ct. of the blood of the beef breeds and possessed the quality and comformation that characterize the typical beef-bred steer. As it was desired that the steers in each lot weigh 900 to 1,000 lbs. when placed on feed, the animals in the higher grades were naturally the youngest, for well-bred and well-developed steers mature earlier and reach a given weight sooner than do scrubs. Thus the steers in Lot I were the youngest steers in the trial, being only 2 years old at the time of marketing. Lot II, choice feeders, were high-grade beef steers possessing large frames and averaging about 6 months older than Lot I. Lot III, good feeders, did not show the quality so manifest in Lots I and II, tho beef blood still predominated and the steers were of better type than the average feeders offered on the central markets. Lot IV, medium feeders, were 3-yr.-olds of mixed breeding, tho carrying some beef blood, and showing coarseness and angularity. Lot V, common feeders, showed little evidence of beef blood. They were rather coarse boned and large headed, were plain thruout, and all showed a lack of quality and conformation. They were the result of indiscriminate breeding and the use of inferior grade bulls. Lot VI, inferior feeders, were scrubs showing no beef blood and were inferior in quality and conformation.

The feeds were the same for all lots. During the first half of the trial the steers were fed cracked ear corn, and later corn-and-cob meal. An average allowance of 2.1 lbs. of cottonseed or linseed meal per head daily was supplied in addition thruout the trial. The roughage, consisting of alfalfa or clover and timothy hay, was cut and mixed with the concentrate allowance. During a part of the trial a small amount of corn stover was given to all lots. The steers were fed in paved feed lots with

[15]Information to the authors. [16]Ill. Bul. 90.

an adjacent open shed. The results secured in the trial are summarized in the following table:

Fattening steers of the various market grades

	Lot I Fancy feeders	Lot II Choice feeders	Lot III Good feeders	Lot IV Medium feeders	Lot V Common feeders	Lot VI Inferior feeders
Wt. at beginning, lbs.	935	1,115	1,019	1,022	966	965
Dry matter in ration per 1000 lbs. live wt.						
Concentrates, lbs.	15.2	16.0	16.0	15.8	15.6	15.2
Roughage, lbs.	6.8	7.0	7.0	7.1	7.1	7.0
Daily gain, lbs.	2.57	2.54	2.34	2.13	2.21	1.96
Dry matter per 100 lbs. gain, lbs.	995	1,209	1,208	1,305	1,200	1,293
Dressed carcass, per ct.	61.6	61.5	60.7	59.7	59.9	59.4
Caul and rough fat, per ct.	9.5	9.7	10.6	10.8	10.1	11.8
Cost of steers per cwt.	$4.75	$4.55	$4.20	$3.85	$3.60	$3.35
Selling price of steers per cwt.*	$7.00	$6.90	$6.50	$5.80	$5.50	$5.40

*On the basis of stationary market prices.

Evidently because considerably younger, the steers in Lot I consumed less dry matter daily per 1,000 lbs. live weight than any of the others, except those in Lot VI. Considering Lots II to VI, the better-bred steers ate slightly more feed per 1,000 lbs. live weight than those of lower grade. The fourth line shows that the feeders of the 3 higher grades made noticeably more rapid gains than those of the lower grades. Lot I made by far the most economical gains, measured either by the dry matter per 100 lbs. gain or by the feed cost of gains, but this was probably due, for the most part, to the fact that these steers were younger than the others.

With the other lots there is no consistent difference in dry matter required per 100 lbs. gain or in the feed cost of the gains. The steers of the better grades yielded a higher percentage of dressed carcass than those of the poorer grades. This was due to their beef conformation and not to any greater degree of finish, for the steers in Lots IV, V, and VI, which were older, were nearer their maximum degree of finish at the end of the trial than the younger steers in Lots I, II, and III. The better steers also had less internal fat but carried a heavier layer of the more valuable surface fat. Tho the lower-grade feeders cost less than the better-bred animals, they were worth correspondingly less when fattened.

718. Amount of feed consumed.—Occasionally the claim is yet advanced that well-bred cattle eat less than natives or scrubs. This opinion is not substantiated by feeding trials nor is it generally held by owners of pure-bred or high-grade stock, who believe rather that the well-bred and well-formed animal has a large capacity to consume feed and convert it economically into meat.

719. Rapidity of gains.—Tests at other stations corroborate the findings of the Illinois Station, that steers of the beef breeds and conformation make larger gains than do those lacking in these points. During 2 years Willson of the Tennessee Station,[17] determining the individual gains of feeders of various types, secured the following results:

Average gains of feeders of various types

Type of feeder	No. of steers	Daily gain Lbs.	Total gain Lbs.
Very good feeder	24	1.76	159
Good feeder	65	1.60	144
Medium feeder	70	1.36	122
Poor feeder	37	1.39	125

The table shows that the very good and good feeders made considerably more rapid gains than those which were classed as medium and poor feeders. The trials at the various stations[18] show that dairy-bred steers, especially those of the larger breeds, do not necessarily make smaller gains than beef-bred steers. This is reasonable, for in the development of both the beef and the dairy breeds one of the chief objects has been the securing of animals with large capacity for food and vigorous assimilative powers. In these qualities the native, or scrub, steer is apt to be lacking.

It is well known that there is great difference in the capacity of individuals of the same breed to make gains when given the same feeds and fed under the same conditions. Bliss and Lee found that in a lot of 8 Hereford-Shorthorn steers fed at the Nebraska Station[19] the best steer gained 166 lbs. more in 154 days than did the poorest. This emphasizes the necessity in scientific trials of selecting uniform animals, feeding as many as possible in each lot so as to eliminate differences due to the individuality of the animals, and of repeating the experiment before drawing hard and fast conclusions. An experienced judge of cattle can generally pick out the good gainers from a bunch of feeders, by selecting those of beef conformation. Such animals are low-set, deep, broad, and compact, with roomy digestive tracts and vigorous constitutions. Smith and Lee[20] found that the middle girth, or the width and depth in the region of the paunch, was a more important factor in determining the rate of gain of steers than the heart girth. The size of bone did not appear to influence the rate of gain, some of the best gainers being large in bone and others small. Cattle feeders well know that temperament is of great importance in determining gain in the feed lot; the calm, quiet animal which eats and then lies down is almost sure to outgain the restless, active one.

[17]Tenn. Bul. 104.
[18]Mich. Buls. 44, 69; Iowa Bul. 20.
[19]Nebr. Bul. 151.
[20]Nebr. Buls. 132, 151, and information to the authors.

720. Early maturity.—The most common claim for superiority with the beef breeds is that such animals mature earlier than others. Experienced feeders know that only the blocky calf of beef conformation is suited for early fattening as baby beef. Tho dairy steers grow rapidly and make large daily gains, they do not become well-finished at as early an age.

721. Dressed carcass.—The following table shows the daily gain from birth and the percentage of dressed carcass yielded by steers of various breeds fattened at several stations[21]:

Daily gain and dressed weight of steers of different breeds

Breed	No. of animals	No. of stations	Av. age	Av. live weight	Daily gain from birth	Limits of dressed weight	Dressed weight
			Days	Lbs.	Lbs.	Per ct.	Per ct.
Hereford	11	4	983	1,515	1.54	63.0–68.0	65.0
Red Poll	2	1	1,000	1,520	1.52	63.8–66.5	65.2
Aberdeen-Angus	16	4	976	1,493	1.53	63.2–69.0	64.8
Swiss	2	1	1,000	1,570	1.57	64.8	64.8
Shorthorn	26	5	1,011	1,510	1.50	62.1–68.0	64.4
Galloway	6	3	923	1,503	1.62	62.0–66.7	63.9
Devon	7	3	1,021	1,376	1.35	62.5–65.8	63.6
Ayrshire	1	1	1,095	1,320	1.20	....	63.3
Sussex	1	1	1,021	1,625	1.59	....	63.0
Holstein	6	3	937	1,469	1.57	60.6–64.4	62.6
Jersey	3	2	1,058	1,440	1.36	58.7–63.9	60.5
Native	9	3	1,038	1,259	1.26	57.9–61.5	60.2

The data referring to daily gain from birth bear out the statement previously made that dairy steers do not necessarily make smaller gains than those of the beef breeds. While the gains of the 3 Jerseys and the single Ayrshire were smaller than of any of the beef breeds, the Holsteins compared favorably with the beef-bred steers. Too few animals of most of the breeds are included to make breed comparisons concerning the yield of dressed carcass. It is evident, however, that the native and dairy steers are inferior to the beef steers, a finding which agrees with the results of the Illinois trial, already discussed.

More important than breed in determining the yield of dressed carcass is the condition, or degree of fatness, of the animal. Mumford points out from the results of the Illinois trial that it is possible to secure reasonably high percentages of dressed beef even from steers of inferior breeding if they are well-finished. He notes the fact that there is more difference in the appearance on foot in the feed lot and gains during fattening between the well-bred steer and the mongrel than there is in the carcasses when the animals have been fed to a high finish.

722. Internal fat.—Trials at the stations show that native and dairy steers have a larger quantity of fat about the internal organs than do

[21] Iowa Buls. 20, 28; Kan. Bul. 51; Mich. Buls. 44, 69; Mo. Bul. 23; Ont. Agr. Col. Rpt. 1892.

beef animals. Commenting on the character of the carcasses of steers of various breeds slaughtered at the Michigan Station,[22] Davenport wrote: "Note the excess of rough tallow in Walton (a Holstein steer) as compared with the others. Walton was 'all cow' as the saying goes, and the fat about his kidneys was astonishing."

There is evidently a specific difference between the beef and dairy breeds in the distribution of fat within the body. It appears that the beef representatives place more of the fat between the fibers of the muscles. On the other hand, steers of the dairy breeds deposit proportionately more fat about the intestines and kidneys. Fat intimately mingled with the muscular fibers of the lean tissues renders such meat tender, juicy, and toothsome. Placed in separate masses anywhere about the body, and especially within the body cavity, it has but low value. Such storage is doubtless best for animals whose function is milk production, but it is certainly against their highest usefulness for beef. In the above characteristic, which sets beef animals somewhat apart from dairy animals, we have a remarkable example of specialization for a definite end, and this lesson is important and far-reaching.

723. Proportion of valuable parts.—Tho somewhat conflicting, the data from the various stations indicate that the well-finished steer of beef conformation yields a somewhat higher percentage of loins and ribs, the most valuable cuts, and less of the cheap parts than do mongrel or dairy steers. This difference is less, however, than many believe. The small difference usually found is due to the fact that the beef steer has a broader back and fuller hind quarters than the native or dairy steer.

724. Quality.—Beyond that which can be expressed in figures or stated percentagely lies that indefinable something described by the word "quality" which enters into all objects of barter. No one can compare a bunch of well-fed beef-bred steers with one representing the dairy breeds or natives without being impressed by a difference not measured by the scales. Speaking of the breed tests at the Iowa Station, Wilson[23] writes: "The carcasses of the dairy breeds lacked in thickness of cuts, and the marbling of the fat and lean was not equal to that of the others (beef breeds)." Georgeson wrote after conducting a trial at the Kansas Station:[24] "The Shorthorns gave the best returns, not simply because the gross weight of their carcasses was greater than that of the scrubs, but also because their meat was esteemed better by experts in the packing-house who were asked to judge of the quality and assign prices." Of a native steer fed in comparison with others of the beef breeds Shaw[25] wrote: "There was a lack of thickness of carcass thruout, the deficiency in the rib and loin being very noticeable, and the absence of what may be termed fleshiness was conspicuous."

The thick-fleshed cuts from well-finished beef steers command a much higher price on the large markets than do the thin-fleshed cuts, thereby giving to the carcass that furnishes them a marked advantage in the

[22]Mich. Bul. 24. [23]Iowa Bul. 20. [24]Kan. Bul. 51. [25]Ont. Agr. Col. Rpt. 1892.

market. In the Iowa trial the carcasses of the beef steers were valued by experts at $1.66 per 100 lbs. higher than those of the dairy steers. In the Kansas trial the loins of the best Shorthorns were rated at 18 cents per pound and of the natives as low as 14 cents.

The matter at issue may be illustrated by a condition in the fruit world: No orchardist will hold that the Baldwin apple tree necessarily grows faster than the seedling apple tree, or that it will make wood and fruit on less material from soil and air. Neither will he hold that Baldwin trees necessarily yield more barrels of fruit than seedlings, nor that a given measure of Baldwin apples contains more juice or human food than the same measure of common seedling apples. Fruit growers do rightfully assert, however, that the market wants Baldwin apples and will pay more for them than for common seedling fruit, due to the fact that their quality is generally far superior, and that from this judgment of the market there is no appeal. Beef cattle have been bred for meat production—it would be passing strange if they did not excel for that purpose.

725. The most profitable type of steer.—For the beef producer who raises the animals he fattens it is evident that well-bred specimens of the beef breeds are the most profitable. The question is more complicated for one who purchases feeders on the market. He must consider the price at which he can secure the various grades and the probable price at which they can be sold when fattened. As Mumford concludes:[26] Opportunities for larger profits, and losses as well, lie with the better grades of feeders, for as a rule the price of common, rough, fat steers fluctuates less than the price for prime steers, and the price of inferior and common feeders varies less than those of the choice and fancy grades. The greater the difference in the price of the various grades of feeders, the more is the advantage in favor of the commoner grades. On the other hand, the greater the difference between the prices for the various grades of fat steers, the more is the advantage in favor of the better feeders. When prices rule low for beef cattle and the market is dull or downward, the range of prices between prime steers and common rough steers is narrow, and as a result, condition or fatness is more important than beef blood. On account of the greater speculation involved in feeding prime or choice feeders, Mumford advises the beginner to first handle a few carloads of the commoner kinds, which must be purchased at correspondingly lower prices, since the margin for profit in feeding low-grade cattle is usually slight.

726. Gains of steers of various breeds.—The most extensive data available concerning the gains made by steers of various breeds are furnished by the records of the Smithfield England Fat-Stock Show.[27] The following table, compiled by the authors from the London Live Stock Journal, summarizes the data for 20 years, 1895 to 1914:

[26] Ill. Bul. 90.

[27] London Live Stock Jour. 1895-1914.

Age, weight and daily gain from birth of steers slaughtered at the Smithfield, England, Fat-Stock Show, 1895-1914

Breed	No. of animals	Age	Weight	Av. daily gain	Breed	No. of animals	Age	Weight	Av. daily gain
		Days	Lbs.	Lbs.			Days	Lbs.	Lbs.
Aberdeen-Angus					*Kerry*				
1 year old....	93	672	1,416	2.11	1 year old....	1	644	658	1.02
2 years old...	86	1,025	1,848	1.83	2 years old...	4	954	1,134	1.18
3 years old...	2	1,269	2,130	1.70	*Red Poll*				
Devon					1 year old....	52	659	1,254	1.90
1 year old....	91	664	1,216	1.82	2 years old...	54	999	1,637	1.64
2 years old...	123	993	1,609	1.63	3 years old...	3	1,247	1,736	1.38
3 years old...	4	1,218	1,753	1.45	*Shorthorn*				
Dexter					1 year old....	85	674	1,446	2.14
1 year old....	47	630	800	1.27	2 years old...	91	1,012	1,901	1.88
2 years old...	51	975	1,039	1.06	3 years old...	4	1,353	2,363	1.74
Galloway					*Sussex*				
1 year old....	72	662	1,229	1.86	1 year old....	98	678	1,463	2.17
2 years old...	73	1,018	1,655	1.63	2 years old...	106	1,015	1,831	1.80
3 years old...	2	1,236	1,794	1.44	3 years old...	5	1,316	2,019	1.53
Hereford					*Welsh*				
1 year old....	77	670	1,426	2.13	1 year old....	76	698	1,463	2.09
2 years old...	84	999	1,844	1.85	2 years old...	90	1,039	1,831	1.76
3 years old...	2	1,316	2,066	1.57	3 years old...	7	1,231	1,919	1.55
Highland					*Cross-bred*				
1 year old....	2	730	1,448	1.98	1 year old....	96	682	1,469	2.15
2 years old...	71	996	1,498	1.51	2 years old...	100	1,006	1,897	1.89
3 years old...	75	1,334	1,806	1.35	3 years old...	4	1,293	2,076	1.60
4 years old...	12	1,704	1,923	1.13					

In the "average daily gain" here given is included in all instances the birth weight of the steer. The table well shows that the daily gain of the highly-fed steer decreases as the animal becomes more mature. The records of the slaughter tests at the Show from 1889 to 1895 show that with steers equally well finished, the more mature the animal, the higher is the percentage of dressed carcass yielded. The average dressing percentage of the 3-yr.-olds was 68.2 per ct. and of the yearlings 65.6 per ct.

III. Miscellaneous Problems in Beef Production

727. Shelter.—A survey of the trials conducted at the Utah, Texas, Kansas, Missouri, Iowa, Minnesota, Ohio, Pennsylvania and Alabama Stations[28] in which steers have been fattened in open sheds with adjacent yards in comparison with others housed in barns shows that the fattening steer, consuming an abundant ration, a considerable portion of which is roughage, has no need for warm quarters. Similar conclusions are reached by Ingle[29] from English trials. Sufficient heat is produced in the body of the steer thru the mastication, digestion, and assimilation of the

[28] Partially reviewed by Armsby, U. S. Dept. Agr., Bur. Anim. Indus., Bul. 108; see also Penn. Rpt. 1906 and Buls. 88, 102; Ala. Bul. 163.

[29] Trans. Highl. and Agr. Soc. Scotland, 1909.

food to maintain the body temperature under ordinary conditions without diminishing the amount of net nutrients available for fattening. (**91**) A reasonable degree of cold is a benefit rather than a detriment, providing the coats of the animals are kept dry. The loss of heat in the evaporation of the water from a wet skin, coupled with that by radiation, may be so great that a portion of the food nutrients is burned up merely to keep the animal warm.

During 7 winters Mairs and Cochel[30] fed one lot of 975-lb. steers in a yard with an open shed for shelter at the Pennsylvania Station, while another lot was confined in a well-ventilated barn. The average gains of the confined steers were no larger than of those sheltered only by the open shed, and practically the same amount of feed was required per 100 lbs. gain by both lots. During the last 5 years when the yard was kept dry by means of cinders, the steers fed therein made larger gains on the average than those in the barn.

Waters fattened one lot of dehorned steers during each of 4 winters at the Missouri Station[31] in an open shed located in a small yard, while a second lot was housed in a comfortable barn, but turned out daily for water and allowed to remain in the yard for 7 hours, except in stormy weather. The steers fed in the open shed made average daily gains of 1.9 lbs., which was 0.2 lb. more than those fed in the barn. They required 10.3 lbs. digestible matter per pound of gain, or 1 lb. less than the steers housed in the warmer and more expensive quarters. During 3 winters Waters also fed similar lots of steers in an open yard without any shelter and with only a pile of corn stalks on which to lie. These steers made slightly larger gains than those fed in the open shed or in the barn, and required no more digestible nutrients per pound of gain.

Feeding in open yards with no shelter other than windbreaks is common in western sections with little rainfall, even in regions with rigorous winters. In experiments at the Manitoba Experimental Farm[32] steers fattened with no shelter except trees and brush made nearly as large gains as others fed in the barn, providing a convenient supply of water was furnished. For humid regions with severe winters an open shed should be provided where the animals may find shelter from storms. Where the winters are mild the saving thru providing shelter may not be great enough to warrant the expense. Gray and Ward[33] found in Alabama that steers fattened in the open in winter made practically as large gains as those allowed access to an open shed. Shelter saved only 6 cents per 100 lbs. of gain in the cost of feed.

From his trials Waters concludes: "It is of more importance that fattening animals lie down regularly and during a large portion of the time than that they be protected from the cold. Abundance of sunshine

[30]Penn. Buls. 64, 68, 74, 83, 88, 102; Rpt. 1906.

[31]Mo. Bul. 76.

[32]Ottawa Expt. Farms Rpts. 1910, 1911, 1912.

[33]U. S. Dept. Agr., Bur. Anim. Indus., Bul. 159.

and fresh air, a comfortable place in which to lie, and freedom from all external disturbances are ideal conditions for large and economical gains.''

Stock cattle being carried over winter are not crowded with heavy rations and hence no great excess of heat is generated in their bodies. The loss of heat by radiation is greater in young animals, for the body surface is larger in proportion to the weight. Yearlings, especially, may hence well be given greater protection than fattening steers, but their quarters should always be well-ventilated. Waters found that yearlings wintered on hay alone or with a small allowance of corn in addition came thru in better condition when housed in an amply ventilated barn and turned out for exercise than when kept in a yard with an open shed. Under usual conditions mature breeding beef cows when in thrifty condition in the fall need no winter shelter other than an open shed.

728. Loose vs. tied steers—At the Ontario Station[34] Day found that box-fed steers made larger and cheaper gains, had better appetites, and did not get off feed as easily as tied steers. Trials at the Ottawa Station[35] by Grisdale were also decidedly in favor of loose box feeding. Not only is there less expense for equipment when this method of feeding is followed but less labor is needed.

729. Self-feeder.—By the use of a large receptacle called a self feeder, cattle may be supplied with concentrates twice a week. At the Illinois Station[36] Mumford and Allison fed 2 lots, each of 17 fleshy 3-yr.-old steers, the following rations for 89 days. Lot I was fed whole clover hay and a concentrate mixture of 7 parts ground corn and 1 part linseed meal separately at regular feeding periods twice daily, while Lot II was supplied chaffed (cut) hay mixed with the concentrates, the whole being fed in a self feeder to which the cattle had access at all times.

Value of self feeder for fattening steers

Average ration	Daily gain	Feed for 100 lbs. gain	
		Concentrates	Clover hay
	Lbs.	Lbs.	Lbs.
Lot. I, hand-fed			
Concentrates, 22.0 lbs. Long hay, 13.5 lbs....	3.0	737	451
Lot II, self-fed			
Concentrates, 24.6 lbs. Chaffed hay, 12.8 lbs..	3.3	743	385

The self-fed steers consumed a heavier concentrate allowance and were brought to full feed in a shorter time without any set back from overeating. Tho consuming more feed than Lot I, this was more than offset by their larger gains. Even after adding the cost of chaffing the hay, the self-fed steers made the cheaper gains. Both systems required about the same amount of labor, but by the use of the self-feeder the necessity for a skilled feeder was reduced. Mumford reports that steers visit the self feeder with remarkable regularity, and once accustomed thereto do not

[34]Ontario Agr. Col., Rpt. 1907.
[35]Ottawa Expt. Farms, Rpt. 1904.
[36]Ill. Bul. 142.

over eat. He holds that the system is often unjustly condemned because careless cattle feeders do not use it properly. Skinner and Cochel[37] found self feeders more generally used in summer than in winter. The grain in the self feeder should be protected from rain and snow and care is necessary to avoid clogging, as an abundance of feed must be available at all times.

730. The paved feed lot.—In parts of the corn belt the feed lot in winter often becomes a sea of mud and mire. Mumford of the Illinois Station[38] fed one carload of steers during winter in a brick-paved lot and another in an ordinary mud lot, both lots having access to an open shed, the bedding in which was kept dry. Due to this fact the paved-lot steers made no cheaper gains than the others. However, because of their dirty appearance, tho not inferior finish, the mud-lot steers sold for 10 cents less per 100 lbs. Pigs following the paved-lot steers gained 1 lb. more from each bushel of corn fed to the steers than did those following the mud-lot steers.

731. Heifers vs. steers.—At the Iowa Station[39] Wilson and Curtiss conducted 2 experiments with steers and spayed and open heifers. The cattle topped their respective classes in the Chicago market, the heifers of the first trial selling for $4.75 and the steers for $5.75 per cwt. on the same market. In the second trial the heifers brought $4.25 and the steers $4.50 per cwt. All lots yielded practically the same amount of dressed carcass, but the heifers yielded about 1 per ct. more in the high-priced cuts of meat. But little, if any, benefit was derived from spaying heifers.

[37] Ind. Cir. 12. [38] Beef Production, p. 155. [39] Iowa Bul. 33.

CHAPTER XXVII

FEEDS FOR FATTENING CATTLE

I. Carbonaceous Concentrates

732. Indian corn.—Of all the concentrates Indian corn is and must continue to be the great fattening feed for cattle in America. While we cannot vie with England in the luxuriance of her pastures, the advantages given the American farmer by the corn crop cannot be surpassed and place us in the very forefront in beef production. No other concentrate is so toothsome and palatable to cattle as the corn grain. Not only is corn loaded with starch but it carries much oil and has but little fiber or other inert matter, the whole forming the best concentrate for quickly filling the tissues of the steer's body with fat, and thereby rendering the lean meat tender, juicy and toothsome. (**201-6**)

Numerous trials at our experiment stations have clearly shown that corn is too low in protein, even for fattening animals, and should therefore be fed with legume hay, or, when carbonaceous roughages only are used, some nitrogenous concentrate should be added to balance the ration. The superior results from properly balanced rations are shown in the following table, in the first division of which are summarized the results of 8 trials, averaging 144 days in length, in each of which corn was fed with carbonaceous roughage, such as timothy hay, prairie hay, corn stover, or kafir stover, to one lot of 2- or 3-yr.-old steers, and with clover or alfalfa hay to others. In the second division the results are given for 4 trials, averaging 132 days, in which the effect of adding a nitrogenous supplement, either linseed meal, cottonseed meal, or gluten feed, to a ration of corn and carbonaceous roughage was studied:

Corn requires supplement for fattening 2-yr.-old steers

Average ration	Initial weight	Daily gain	Feed for 100 lbs. gain Concentrates	Roughage
*Legume hay as supplement to corn**	Lbs.	Lbs.	Lbs.	Lbs.
Unbalanced ration, 90 steers				
Corn, 15.2 lbs.				
Carbonaceous roughage, 13.0 lbs.........	959	1.7	930	832
Balanced ration, 71 steers				
Corn, 15.4 lbs.				
Legume hay, 13.2 lbs....................	952	2.3	689	575
Nitrogenous concentrate as supplement to corn†				
Unbalanced ration, 44 steers				
Corn, 16.3 lbs.				
Carbonaceous roughage, 8.3 lbs..........	995	1.6	1,082	522
Balanced ration, 54 steers				
Corn, 16.7 lbs.				
Nitrogenous supplement, 2.1 lbs.				
Carbonaceous roughage, 8.6 lbs..........	1,002	2.2	862	402

*Average of 1 trial by Haney (Kan. Bul. 132), 2 by Burtis (Okla. Rpts. 1900, 1901), 1 by Mumford (Ill. Bul. 83), 2 by Skinner and Cochel (Ind. Buls. 115, 129), and 2 by Smith (Nebr. Buls. 90, 93).

†Average of 1 trial by Mumford (Ill. Bul. 83), 1 by Skinner and Cochel (Ind. Bul. 115), and 2 by Smith (Nebr. Buls. 90, 93).

While the steers fed corn and legume hay gained 2.3 lbs. per head daily, the daily gain of those fed corn and carbonaceous roughage was only 1.7 lbs., and these steers, receiving the unbalanced ration, required 35 per ct. more corn and 44 per ct. more roughage per 100 lbs. gain. Where the ration of corn and carbonaceous hay was supplemented by 2.1 lbs. of a nitrogenous concentrate, the steers made 37 per ct. larger gains and required much less feed per 100 lbs. of gain. When the corn allowance is properly balanced, not only is the feeding value of this grain greatly increased with both the cattle and the pigs which follow the steers, but it keeps the animals more healthy, shortens the feeding period and gives a higher finish than can be secured with unbalanced rations.

When other carbonaceous concentrates, such as barley, wheat, kafir, milo, hominy feed, or dried beet pulp, are fed it is just as important that protein-rich feed be included in the ration as when the chief concentrate is corn.

733. Adding a nitrogenous concentrate to corn and clover hay.—To determine whether it was profitable to add a nitrogenous concentrate to a ration of corn and clover hay for fattening 2-yr.-old steers, Skinner and Cochel conducted 2 trials at the Indiana Station,[1] and Mumford 1 trial at the Illinois Station[2] for periods averaging 172 days, with the results summarized in the following table:

Adding a nitrogenous concentrate to corn and clover hay for steers

Average ration	Initial weight	Av. daily gain	Feed for 100 lbs. gain Concentrates	Hay
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I, 35 steers				
Corn, 18.4 lbs.*				
Clover hay, 9.4 lbs.	1,032	2.0	940	484
Lot II, 35 steers				
Corn, 17.7 lbs.*				
Nitrogenous concentrate, 2.9 lbs.				
Clover hay, 9.1 lbs.	1,047	2.4	854	376

*Ear corn fed in the Illinois trial has been reduced to the equivalent of shelled corn.

In each of the 3 separate trials Lot II, receiving a nitrogenous concentrate (cottonseed meal or linseed and gluten meal) in addition to corn and clover hay, made larger and more economical gains from the standpoint of feed required per 100 lbs. gain. With feeds at the market prices, the gains were also cheaper than in Lot I. Due to better finish the steers in Lot II sold for a higher price in both trials, bringing 25 cents more per 100 lbs. on the average than those in Lot I.

Whether it will pay to add a nitrogenous concentrate to a ration of corn and legume hay will depend on the relative prices of these feeds. Steers supplied all the corn and legume hay they will clean up, during the early part of the fattening period eat a much larger proportion of hay than during the later stages. Until well advanced in fattening they will eat

[1]Ind. Buls. 129, 136. [2]Ill. Bul. 103.

enough hay to balance their ration fairly well. Later, as the proportion of corn increases, the ration becomes unbalanced and there will be more benefit from the addition of a nitrogenous concentrate. With alfalfa hay for roughage, there is less need of adding protein-rich concentrates than with clover, which is lower in protein than alfalfa.

734. Heavy vs. light corn feeding.—When corn was low in price, fattening steers on full feed in the corn belt were commonly given all the corn they would clean up. In recent years, with corn higher in price, it is often more economical to restrict the allowance and thereby induce the steers to eat a larger proportion of roughage. At the Nebraska Station[3] Smith fed 2 lots, each of 10 steers grown under range conditions and averaging 978 lbs., the first for 140 and the second for 168 days, on light and heavy rations of corn together with alfalfa hay and corn stover, with the results shown in the table:

Heavy and light corn feeding for steers

Average ration	Daily gain	Gain per head	Feed for 100 lbs. gain Corn	Feed for 100 lbs. gain Roughage
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I				
Corn, 22.3 lbs.				
Alfalfa hay, 4.9 lbs.				
Corn stover, 4.9 lbs.	2.4	339	922	403
Lot II				
Corn, 13.9 lbs.				
Alfalfa hay, 10.9 lbs.				
Corn stover, 7.2 lbs.	2.0	339	691	896

Lot II, fed the light allowance of corn, gained 0.4 lb. less per head daily and required 168 days to put on 339 lbs., the same amount that Lot I did in 140 days. The steers in Lot II required 25 per ct. less grain per 100 lbs. gain than Lot I, but over twice as much hay. In another trial Smith found that 870-lb. steers fed 12.0 lbs. of corn meal and 17.2 lbs. of alfalfa, made practically as rapid gains as others fed 18.8 lbs. of corn meal and 8.7 lbs. of alfalfa. The heavy-fed steers required 36 per ct. more corn per 100 lbs. gain but only half as much hay as those fed the light allowance of corn.

Cochel and Doty found at the Pennsylvania Station[4] that 2-yr.-old steers fed a full allowance of corn, supplemented by cottonseed meal, and with corn stover, corn silage, and mixed hay for roughage, gained only 0.15 lb. more per head daily than others fed two-thirds as much corn. The steers on the lighter feed of corn made cheaper gains and returned the greater profit.

The amount of corn to be fed should be governed by the relative price of corn and roughage and by the time it is desired to have the cattle ready for market.

735. Preparation of corn for beef cattle.—The practice of successful stockmen in the corn belt and trials at the experiment stations show that,

[3]Nebr. Buls. 100, 114. [4]Penn. Bul. 102.

in general, getting corn to cattle in the simplest manner and with the least preparation and handling is the most economical, when pigs follow the steers to consume any grains which escape mastication. Waters,[5] gathering replies from hundreds of cattle feeders in Missouri, Iowa, and Illinois, found that 50 per ct. fed husked or unhusked ear corn, 25 per ct. shelled corn, and the remainder, crushed, soaked, or ground corn. Only 3 per ct. fed ground corn as a regular practice. Skinner and Cochel[6] report that of 929 Indiana feeders 73 per ct. used broken ear corn at some time during the feeding period, 46 per ct. shock corn at some time, 35 per ct. snapped corn, 27 per ct. corn-and-cob meal, and 21 per ct. used shelled corn.

In finishing prime beeves many skilled feeders seek to "keep the feed better than the cattle," i.e., prepare the feed more as the cattle gain in flesh. Thus, they may start the steers on shock corn, then as they require more concentrates, add snapped corn or ear corn; still later the ear corn is broken or shelled; and at the close of the fattening period, to tempt the steers to consume a heavier allowance of grain, corn meal or corn-and-cob meal is employed.

Silage from well-matured corn is the most palatable form in which the entire corn plant can be offered to the steer. In addition to the grain in this succulent feed, some additional corn should be fed, usually in the form of ear corn or shelled corn. Next to silage, corn is never so palatable to the steer as when given unhusked on the stalk, for there is an aroma and palatability about the ear in Nature's own wrappings that every steer recognizes and appreciates. Such being the case, wherever possible let shock corn with its wealth of ears be thrown into the long feed racks standing in the open lot or under the shed and allow the steers to do their own husking and grinding. Where corn cannot be fed unhusked, ear corn should be given, whole, chopped, or split, as best suits the animal. Corn long stored in the crib becomes dry and hard, losing fragrance and aroma thru exposure to air and vermin. For summer feeding such grain should be specially prepared by soaking or shelling, or possibly by grinding. Corn should be soaked from 12 to 18 hours, care being taken to change the water frequently and to keep the feed boxes clean and sweet. Old cattle can utilize ear corn, stover, and coarse feed more advantageously than can younger animals.

To induce young steers to consume sufficient corn to overcome their tendence to grow rather than to fatten, more preparation of the corn is warranted than with older animals. (**423**)

736. Feeding corn in various forms.—To determine the economy of preparing corn in various ways, Mumford fed 5 lots of choice 1000-lb. feeders the rations shown in the table for 186 days at the Illinois Station.[7]

[5] Mo. Bul. 76. [6] Ind. Cir. 12. [7] Ill. Bul. 103.

Feeding corn in various forms to fattening steers

Average ration	Daily gain	Feed for 100 lbs. gain		Pigs per 10 steers	Gain of pigs per 100 lbs. corn fed to steers	Feed cost returned by pigs
		Concentrates	Roughage			
	Lbs.	Lbs.	Lbs.	No.	Lbs.	Per ct.
Lot I, 15 steers Ear corn, 20.1 lbs. Gluten or oil meal, 2.9 lbs. Clover hay, 8.0 lbs.	2.3	986	344	5	1.7	9.7
Lot II, 15 steers Corn-and-cob meal, 20.0 lbs. Gluten or oil meal, 2.9 lbs. Clover hay, 8.1 lbs.	2.3	993	350	3	0.5	2.6
Lot III, 10 steers Shelled corn, 16.6 lbs. Gluten or oil meal, 3.0 lbs. Clover hay, 9.0 lbs.	2.0	984	454	7	3.6	16.7
Lot IV, 15 steers Corn meal, 16.6 lbs. Gluten or oil meal, 2.9 lbs. Clover hay, 8.7 lbs.	2.4	822	370	3	0.7	3.0
Lot V, 10 steers Ear corn, 13.5 lbs. Oil meal, 1.4 lbs. Shock corn, 14.7 lbs. Clover hay, 7.2 lbs.	2.1	991*	782	6	1.8*	12.7

*Including ear corn in the shock corn.

While the steers in Lot IV, fed corn meal, made the largest gains and required the least feed for 100 lbs. gain, for combined gains of steers and pigs ear corn proved the most economical. Lot III, getting shelled corn, made the poorest gains, due to the fact that, as shown by the gains of the pigs following, the steers in this lot did not masticate their corn so thoroly as the others. While about the same amount of concentrates was required for 100 lbs. gain as with Lots I and II, it must be remembered that the ear corn and the corn-and-cob meal rations contained over 17 per ct. cob. Thus shelled corn proved inferior to ear corn or corn-and-cob meal in beef production. Lot V, fed shock corn at first and ear corn during the finishing period, made larger gains than Lot III, fed shelled corn. In economy of combined gains of steers and pigs the shock-corn ration ranked second.

Where shelled corn was fed, the 7 hogs following each 10 steers gained 3.6 lbs. from each 100 lbs. of corn fed to the steers, the hogs returning 16.7 per ct. of the value of the corn given to the steers. Where ground corn was fed, the hogs returned but 0.7 lb. increase for 100 lbs. of corn fed to the steers, and corn-and-cob meal made still poorer returns.

Good of the Kentucky Station[8] finds that steers fed silage often fail to eat sufficient corn when it is supplied in the form of ear corn, possibly due to the fact that the silage makes their gums tender. By feeding shelled corn this difficulty is obviated.

[8]Information to the authors.

737. Soft corn.—Kennedy and Rutherford of the Iowa Station,[9] studying the feeding value of soft corn with 2 lots of 8 steers each, fed for 6 months, found that soft corn, containing 35 per ct. of moisture at the beginning of the trial and 16 per ct. at its close, made rather more economical gains than mature corn, taking dry matter as the basis of comparison, and that the cattle finished equally well on it. (**205**)

738. Barley.—In sections of the West where corn does not thrive, barley is of much importance as a grain for fattening cattle. To compare this grain with corn, Wilson fed 866-lb. steers the rations shown below in 2 trials at the South Dakota Station[10] averaging 108 days in length:

Barley vs. corn for fattening steers

Average ration	Daily gain	Feed for 100 lbs. gain Concentrates	Corn silage
	Lbs.	Lbs.	Lbs.
Lot I, 8 steers			
Ground barley, 14.8 lbs.			
Linseed meal, 1.5 lbs. Corn silage, 14.2 lbs....	2.1	790	674
Lot II, 8 steers			
Ground corn, 16.8 lbs.			
Linseed meal, 1.7 lbs. Corn silage, 14.2 lbs....	2.2	856	648

The steers fed barley did not consume quite as much grain as those fed the more palatable corn and hence did not make quite as rapid gains. However, less concentrates were required for 100 lbs. gain than with corn. In a trial at the Hays, Kansas, Station[11] Haney secured similar results with 8- to 10-months-old steer calves fed alfalfa hay and either ground barley or corn-and-cob meal. The calves fed corn gained 0.2 lb. more per head daily, but required 5 per ct. more grain than those fed barley. (**226**)

739. Wheat.—This grain is not commonly fed to cattle except when off grade or unusually low in price. Linfield of the Montana Station[12] found wheat and barley of practically the same value when fed in limited allowance with clover hay to 936-lb. steers. At the Nebraska Station[13] Burnett and Smith found wheat superior to corn for fattening yearling steers, when fed with 20 to 30 per ct. of bran and linseed meal along with alfalfa hay, prairie hay, and wheat straw for roughage. Two-yr.-old steers fed ground wheat and alfalfa hay in a trial by Haney at the Hays, Kansas, Station[14] gained 0.45 lb. less per head daily than others fed ground corn, due to the fact that the wheat was less palatable and hence the steers ate less grain than those fed corn. The wheat-fed steers, however, required less grain per 100 lbs. gain. We may conclude that, while steers fed wheat may consume less grain than others fed an unlimited allowance of corn, no more wheat than corn is required for 100 lbs. gain.

[9]Iowa Bul. 75.
[10]S. D. Bul. 160.
[11]Kan. Bul. 128.
[12]Mont. Bul. 58.
[13]Nebr. Bul. 75.
[14]Kan. Bul. 128.

At the North Dakota Station[15] Sheppard and Richards found that fattening steers fed low-grade ground wheat and bran, with poor quality hay for roughage, required about twice as much feed per 100 lbs. gain as others fed corn meal. The wheat-fed steers grew rather than fattened, indicating that low-grade wheat, which is usually higher in protein than wheat of good quality, should be used for growing animals rather than for fattening ones. (**215**)

740. Oats.—Since oats are usually high in price compared with other grains, they are seldom used as the sole concentrate for fattening, tho they are well liked by cattle and produce beef of good quality. In 2 trials of 101 and 115 days, respectively, Wilson of the South Dakota Station[16] fed steers averaging 875 lbs. about 14 lbs. of corn silage per head daily and concentrates as shown in the table, to compare the value of ground oats and ground corn:

Oats vs. corn for fattening steers

Average concentrate allowance	Daily gain	Feed for 100 lbs. gain Concentrates	Silage
	Lbs.	Lbs.	Lbs.
Lot I, Oats 15.0 lbs. Linseed meal, 1.5 lbs.	2.0	862	746
Lot II, Corn, 16.8 lbs. Linseed meal, 1.7 lbs.	2.2	856	648

The first year the oat-fed steers made as large gains as those fed corn, but the second year when the oats were rather light in weight, the corn-fed steers made better gains. The table shows that the steers fed oats required about the same amount of concentrates for 100 lbs. of gain as those fed corn, but consumed somewhat more silage. Linfield at the Montana Station[17] found oats, wheat, and barley about equally effective when fed with clover hay to fattening steers. A mixture of the 3 grains was somewhat superior to any single one. Oats are excellent for growing cattle, and are also useful for mixing with corn in starting cattle on feed, especially calves being fattened for baby beef. For fattening cattle oats should be ground, as any whole grains escaping mastication are not so readily recovered by pigs as is corn. (**223**)

741. Kafir.—Thruout the southern portion of the great plains region the grain sorghums are of great importance in the feeding of beef cattle. The following table presents the results of 3 trials, averaging 138 days, in which ground kafir and alfalfa hay were fed to one lot of steers, and ground corn and alfalfa hay to another lot. In the second division of the table are summarized the results of 4 trials, averaging 148 days, in which these grains were fed as the sole concentrate with kafir or sorghum fodder or kafir stover. Corn or kafir with these carbonaceous roughages made an unbalanced ration, from which as good gains could not be expected as from corn or kafir with alfalfa hay.

[15] N. D. Bul. 73. [16] S. D. Bul. 160. [17] Mont. Bul. 58.

Kafir vs. corn in balanced and unbalanced rations

Average ration	Initial weight	Daily gain	Feed for 100 lbs. gain Grain	Roughage
	Lbs.	Lbs.	Lbs.	Lbs.
*With alfalfa hay**				
Lot I, total of 18 steers				
Ground kafir, 16.7 lbs.				
Alfalfa hay, 15.1 lbs.	952	2.4	697	636
Lot II, total of 18 steers				
Ground corn, 15.5 lbs.‡				
Alfalfa hay, 15.2 lbs.	943	2.5	612	610
With carbonaceous roughage†				
Lot I, total of 35 steers				
Ground kafir, 18.1 lbs.				
Carbonaceous roughage, 14.6 lbs.	958	1.7	1,081	936
Lot II, total of 31 steers				
Ground corn, 16.7 lbs.‡				
Carbonaceous roughage, 14.8 lbs.	953	1.8	934	872

*Average of 2 trials by Burtis (Okla. Rpts. 1899, 1900, 1901) and 1 by Haney (Kan. Bul. 132).
†Average of 2 trials by Burtis (Okla. Rpts. 1900, 1901), 1 by Georgeson (Kan. Bul. 67), and 1 by Haney (Kan. Bul. 132).
‡Corn-and-cob meal fed in trial by Haney reduced to equivalent of ground corn.

These trials well show the value of kafir for fattening steers. When given alfalfa hay, the steers fed kafir required only 14 per ct. more kafir grain for 100 lbs. gain than those fed corn. With poorly balanced rations of carbonaceous roughage and either kafir or corn, about 16 per ct. more kafir than corn was consumed per 100 lbs. gain. (237)

742. Milo and kafir vs. corn.—At the Texas Station[18] Burns fed 3 lots, each of six 2-yr.-old grade Angus steers averaging about 875 lbs. in weight, 12.6 lbs. of cottonseed hulls and 3.0 lbs. of cottonseed meal per head daily with 15.1 lbs. of corn chop, milo chop, or kafir chop, for 120 days with the results shown in the table. The grains were all ground to the same fineness.

Milo and kafir compared with corn for fattening steers

Concentrate allowance	Daily gain	Feed for 100 lbs. gain Concentrates	Hulls
	Lbs.	Lbs.	Lbs.
Lot I, Corn and cottonseed meal	2.1	858	599
Lot II, Milo and cottonseed meal	2.1	853	596
Lot III, Kafir and cottonseed meal	2.5	731	510

Fed with cottonseed meal and cottonseed hulls, kafir produced the largest and most economical gains, and milo proved equal to corn. There was no material difference in the quality of meat from the 3 lots. (238)

743. Emmer (spelt).—To compare the value of ground emmer and ground corn for fattening steers, Wilson conducted 2 trials at the South Dakota Station[19] in which 880-lb. steers were fed an average of 14 lbs. corn silage per head daily with the concentrate allowances shown in the table for periods averaging 108 days:

[18] Tex. Bul. 110.
[19] S. D. Bul. 160.

Emmer vs. corn for fattening steers

Average concentrate allowance		Daily gain	Feed for 100 lbs. gain Concentrates	Silage
		Lbs.	Lbs.	Lbs.
Lot I, Emmer, 16.7 lbs.	Linseed meal, 1.7 lbs.	2.2	840	648
Lot II, Corn, 16.8 lbs.	Linseed meal, 1.7 lbs.	2.2	856	648

In this fairly well balanced ration ground emmer was fully equal to ground corn. Wilson concludes that under South Dakota conditions emmer is the best small grain to grow for feeding with corn silage. In a previous trial at the same Station[20] in which the unbalanced rations of prairie hay and either corn or emmer were fed, Wilson and Skinner found that it required 125 lbs. of emmer to replace 100 lbs. of corn. Fed to calves fattened for baby beef,[21] emmer produced a hard fat the same as did oats, and meat of as good quality as that from corn. (**233**) Emmer closely resembles oats in composition, having considerable bulk, and therefore should be especially useful in starting cattle on feed. (**740**)

744. Millet.—That the seed of hog, or broom-corn, millet, which is a reliable grain crop on the northern plains, is a satisfactory feed for fattening cattle was shown by Wilson and Skinner at the South Dakota Station.[22] Calves weighing about 500 lbs. fattened for baby beef on ground millet and clover hay gained 1.5 lbs. per head daily for 431 days, while others fed corn and clover hay gained 1.8 lbs. The steers fed millet required 6 per ct. more grain and 32 per ct. more hay for 100 lbs. gain than those fed corn. Millet produced carcasses of as good quality as corn, but with somewhat softer fat. (**243**)

745. Rough rice and by-products.—In feeding trials with steers at the Texas Station[23] Craig and Marshall found that when fed with cottonseed meal and cottonseed hulls 2.3 lbs. of ground rough rice was equal to 1 lb. of cottonseed meal in the ration. Ten lbs. of rice bran proved equal to 6 lbs. of cottonseed meal when forming two-fifths of the concentrates of the ration. Rice polish was about equal to cottonseed meal. Rice hulls proved to be without value. Cruse secured satisfactory results with a ration of 7.3 lbs. rough red rice (a pest in the rice fields), 4.2 lbs. cottonseed meal, and 12.5 lbs. Johnson grass hay in a trial at the Fort Worth, Texas, Substation.[24] Rice should always be ground for cattle. (**234**)

746. Sugar-beet pulp.—In the vicinity of the western beet sugar factories thousands of cattle are fattened annually on beet pulp with alfalfa hay, which admirably supplements the protein-poor pulp, and usually with a limited allowance of grain in addition. To study the most profitable method of feeding pulp Carlyle and Griffith fed 4 lots, each of twelve 956-lb. steers, the rations shown in the table for 100 days at the Colorado Station.[25] Alfalfa hay of poor quality was fed to all without limit.

[20] S. D. Bul. 100.
[21] S. D. Bul. 97.
[22] S. D. Bul. 97.
[23] Tex. Buls. 76, 86.
[24] Tex. Bul. 135.
[25] Colo. Bul. 102.

Value of wet beet pulp in steer feeding

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Hay Lbs.	Beet Pulp Lbs.
Lot I				
Beet pulp, 93.4 lbs.				
Alfalfa hay, 20.0 lbs. Ground corn, 6.6 lbs...	2.6	251	759	3,545
Lot II				
Alfalfa hay, 31.3 lbs. Ground corn, 6.6 lbs...	1.8	376	1,778	....
Lot III				
Beet pulp, 97.3 lbs.				
Alfalfa hay, 21.9 lbs.	1.8	....	1,189	5,283
Lot IV				
Alfalfa hay, 41.5 lbs.	1.5	....	2,829	....

The steers in Lot I, fed an unlimited allowance of wet beet pulp and alfalfa hay with 6.6 lbs. of corn per head daily, made the excellent daily gain of 2.6 lbs. each, considerably larger than that of Lot II, fed only alfalfa hay and corn, or Lot III, fed beet pulp and hay, with no corn. Thruout the trial the pulp-fed steers were more thrifty than those getting no pulp. The conclusion was that for 2-yr.-old fattening steers 1 ton of wet beet pulp was equal to 620 lbs. of alfalfa hay or 220 lbs. of ground corn. In feeding this succulent food, care should be taken that refuse pulp does not accumulate in the troughs and decompose. Animals should be gradually accustomed to the pulp, later being usually given all they will clean up. **(274)**

747. Dried beet pulp.—Shaw and Norton of the Michigan Station[26] found as the result of 3 winter trials that dried beet pulp tended to growth with cattle rather than to fattening, and conclude that while in the earlier part of the feeding period dried pulp can be fed advantageously in large quantities because it produces rapid gains, during the finishing period it should be largely replaced by corn meal. They found a 1000-lb. steer will not consume over 10 lbs. of dried beet pulp daily. **(275)**

748. Molasses.—In the sugar-cane districts of the South, cane molasses is an economical carbonaceous concentrate for cattle. In a 120-day trial at the Texas Station[27] Burns fed 2 lots, each of 6 high-grade 2-yr.-old Aberdeen-Angus steers, averaging about 870 lbs., a basal ration of 12.6 lbs. cottonseed hulls and 3 lbs. cottonseed meal, with corn or corn and blackstrap molasses, as shown in the table:

Cane molasses as a partial substitute for corn

	Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Hulls Lbs.
Lot I,	Corn, 15.1 lbs. Basal ration	2.1	858	599
Lot II,	Molasses, 6.5 lbs.			
	Corn, 8.6 lbs. Basal ration	2.3	798	559

[26]Mich. Bul. 247. [27]Tex. Bul. 110.

When 6.6 lbs. of molasses replaced an equal weight of corn the gains were slightly increased and less feed was required for 100 lbs. gain, showing molasses to be somewhat the higher in feeding value per pound, when replacing not more than half the corn in the ration.

In a 140-day trial at the Pennsylvania Station[28] Tomhave and Severson fed a lot of six 1040-lb. choice feeders all the corn and mixed hay they would consume, in addition to 20 lbs. of corn silage per head daily and 2.5 lbs. of cottonseed meal daily per 1,000 lbs. live weight. Another lot was given the same feeds with 5 lbs. of molasses in addition. The steers fed 5 lbs. of molasses per head daily made no larger gains than the first lot, and their gains were more expensive, with molasses at $20 per ton and shelled corn at 70 cents per bushel.

At the Indiana Station[29] Skinner and King found in a 150-day trial that steers fed 2.8 lbs. molasses, 10.9 lbs. shelled corn, and 3.3 lbs. cottonseed meal gained 0.34 lb. more per head daily than others fed 13.6 lbs. shelled corn and 3.3 lbs. cottonseed meal, both lots receiving corn silage and clover hay without limit in addition. The steers fed molasses consumed over 4 lbs. more silage per head daily than the others. With corn ranging from $21.60 to $24.75 per ton and molasses at 13.5 cents per gallon ($22.50 per ton), the steers fed molasses made the cheaper gains. From these trials we may conclude that in the North as heavy an allowance of molasses as 5 lbs. per head daily is not ordinarily economical, tho a small amount may be profitable in stimulating the appetite. Molasses is especially useful in getting animals to clean up roughage which would otherwise be unpalatable.

Ware[30] reports that beet molasses has been fed to oxen for many years at the Hohenau sugar factory, Germany. During the first month 3.3 lbs. is fed per head daily, and after this 4.4 lbs., the molasses being mixed with beet pulp. The oxen so fed have better appetites than those fed no molasses, and fatten rapidly. Not more than 4 to 8 lbs. of beet molasses daily per 1,000 lbs. live weight should be fed to fattening cattle. When fed at this maximum rate of 8 lbs. per head daily, with alfalfa hay valued at $3.50 per ton and bran and shorts at $14 per ton, molasses was worth only $2.35 per ton for fattening steers. Morton[31] of the Colorado Station states that the use of molasses is greatly increasing in the beet-sugar districts. The molasses is spread over hay or cut straw, either by means of a force pump on an ordinary wagon water tank, or is thinned with water and poured over it from buckets. Large feeders heat the molasses in tanks and mix it with cut hay or straw in mixing machines. (276)

749. Hominy feed.—At the Kansas Station[32] Cochel fed 2 lots each of fifteen 540-lb. calves for baby beef on 19.7 lbs. sorghum silage, 1.7 lbs. cottonseed meal, and either 9.3 lbs. ground corn or 8.9 lbs. hominy feed per

[28] Information to the authors.

[29] Information to the authors.

[30] Cattle Feeding, p. 245.

[31] Information to the authors.

[32] Kansas Industrialist, May 1, 1915; information to the authors.

head daily for 120 days. For the first 2 months the hominy-fed calves made the most rapid gains, but later they were passed by those fed on corn, apparently because they would not eat as heavy an allowance of hominy feed, which is rather high in fat. The hominy-fed calves gained 1.87 lbs. per head daily and those fed corn 1.96 lbs., the feed requirements per 100 lbs. gain being practically the same for the 2 lots. (**213**)

II. Nitrogenous Concentrates

750. Cottonseed meal.—This rich concentrate is the basis of the fattening of beef cattle in the South and is widely used in the northern states as a supplement to rations deficient in protein. Trials at the Indiana Station, which are reviewed later (**777**), show that 2.5 lbs. of cottonseed meal per head daily per 1,000 lbs. live weight is sufficient to balance a ration of shelled corn, corn silage, and oat straw or clover hay. In the South, owing to the cheapness of cottonseed meal, it is commonly fed as the sole concentrate. Since the meal is a heavy, highly nitrogenous feed, and is poisonous to fattening cattle when fed in excess, the determination of the allowance to be fed for the best results is of great importance. (**249-50**)

During each of 3 years Willson fed 2-yr.-old steers, averaging 944 lbs. in weight, for 90-day periods at the Tennessee Station[33] on corn silage and different amounts of cottonseed meal, as is shown in the table. The steers fed low cottonseed meal allowances received 3 lbs. of meal for the first 30 days, 4 lbs. for the second 30 days, and 5 lbs. for the last month. Those on medium allowances received 4 or 5 lbs. for the first month, 5 or 6 for the second, and 6 or 7 for the third, while those on the heavy allowances received 7, 8, and 9 lbs. respectively, for the 3 months of the feeding period.

Low, medium, and heavy allowances of cottonseed meal

Average ration	Daily gain	Feed for 100 lbs. gain		Cost of 100 lbs. gain*
		Meal	Silage	
	Lbs.	Lbs.	Lbs.	Dollars
Low allowance, total of 32 steers				
Cottonseed meal, 4 lbs. Corn silage, 56 lbs.	1.62	253	3,542	8.47
Medium allowance, total of 24 steers				
Cottonseed meal, 6 lbs. Corn silage, 52 lbs.	1.70	335	3,124	8.87
Heavy allowance, total of 24 steers				
Cottonseed meal, 8 lbs. Corn silage, 59 lbs.	1.66	491	3,622	11.56

*Cottonseed meal at $25 and corn silage at $3 per ton.

In none of the trials did the heavy allowance of cottonseed meal produce larger gains than the medium allowance. On the average the medium allowance made slightly larger but more expensive gains than the low allowance. Willson concludes that the use of as much as 7 to 9

[33] Tenn. Bul. 104.

lbs. of cottonseed meal per head daily is uneconomical except for short feeding periods of only 30 to 50 days.

Since the feeders of the south Atlantic states have access to the large eastern markets, which demand well-finished cattle, Gray and Curtis conducted trials at the North Carolina Station[34] to determine the maximum amount of cottonseed meal which could be fed with good results to 2-yr.-old steers with corn silage or cottonseed hulls given in unlimited amount. In a 99-day trial 8 lots, each of 9 to 10 steers, were fed the allowances of cottonseed meal shown in the table.

Amount of cottonseed meal to feed with corn silage or cottonseed hulls

Average daily allowance of meal	Daily gain	Feed cost of 100 lbs. gain*	Selling price per 100 lbs.
	Lbs.	Dollars	Dollars
Corn silage for roughage			
Lot I, Cottonseed meal, 6.0 lbs.	1.19	11.39	7.90
Lot II, Cottonseed meal, 7.5 lbs.	1.49	10.34	8.00
Lot III, Cottonseed meal, 9.0 lbs.	1.76	9.79	8.20
Lot IV, Cottonseed meal, 10.5 lbs.	1.89	10.03	8.40
Cottonseed hulls for roughage			
Lot V, Cottonseed meal, 6.0 lbs.	1.43	9.86	7.90
Lot VI, Cottonseed meal, 7.5 lbs.	1.55	10.30	8.00
Lot VII, Cottonseed meal, 9.0 lbs.	1.59	11.17	8.15
Lot VIII, Cottonseed meal, 10.5 lbs.	1.45	13.29	8.00

*Cottonseed meal, $25; cottonseed hulls, $6; and corn silage, $3.50 per ton.

With corn silage for roughage the allowance of 10.5 lbs. of cottonseed meal produced the largest gains and the highest finish, as shown by the selling price, and brought the most profit. The gains were, however, cheaper when 9 lbs. of meal was fed. With hulls the gains were largest, the finish highest, and the profit greatest on the allowance of 9 lbs. of meal. In another trial lasting 107 days with 4 lots, each of 20 steers, 9 lbs. of meal fed with silage made smaller gains than 7.5 lbs., but produced slightly better finish. When fed with hulls 9 lbs. of meal produced decidedly lower gains at a much higher cost than 7.5 lbs. From these and other trials Curtis concludes that cattle fed 7.5 lbs. of meal per head daily with either silage or hulls will continue to gain and finish quite satisfactorily for 130 to 140 days, which is the maximum period for feeding this allowance with hulls. With corn silage the feeding period may be extended 30 to 50 days or even somewhat longer without harm. When 9 to 10.5 lbs. of meal is fed with hulls, the daily gains decrease after 120 to 130 days until finally the animal begins losing weight. The same amount of meal may be fed with silage for 30 to 60 days longer with continuous gains and consequent high finish. The retarding of the poisonous effect of cottonseed meal by silage seems to be due to the succulent nature of the silage, for the same effect is also produced by pasturage. Owing to the protein-rich nature of cottonseed meal, with young steers it tends to produce growth rather than to fatten; hence 2- or 3-yr.-olds are best suited for heavy cottonseed meal

[34]Information to the authors.

feeding. When fattening yearlings on cottonseed meal, McLean of the Mississippi Station[35] recommends that they be given not over 5 lbs. per head daily.

Gray and Ward [36] found a daily allowance of 2.3 lbs. cottonseed meal and 1.2 lbs. corn-and-cob meal somewhat superior, for 6- to 8-months old calves fed for baby beef, to an allowance of 3.1 lbs. cottonseed meal, cottonseed hulls and mixed alfalfa and grass hay being fed to both lots. In feeding cottonseed meal it is exceedingly important that the steers be started on the feed slowly, as many animals are injured by failure to observe this precaution.

Soule of the Georgia Station[37] states that with cattle to be fed 180 days about 4 lbs. per head daily is enough for the first 60 to 90 days, the allowance eventually being increased to 8 to 10 lbs. The meal should also be mixed thoroly with the roughage, so that the greedy steer will not be able to gorge on the meal.

751. Cold-pressed cottonseed cake.—To compare the value of cold-pressed cottonseed cake, or "caddo cake," with choice cottonseed meal, Kennedy and Robbins fed 2 lots, each of seven 714-lb. steers, the following rations at the Iowa Station[38] for 168 days:

Caddo cake vs. cottonseed meal for fattening steers

Average ration	Daily gain	Feed for 100 lbs. gain: Cake or meal	Corn	Hay
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I				
Caddo cake, 4.4 lbs.				
Corn-and-cob meal, 14.4 lbs. Clover hay 5.3 lbs.	1.8	239	793	290
Lot II				
Cottonseed meal, 3.1 lbs.				
Corn-and-cob meal, 14.2 lbs. Clover hay, 5.4 lbs.	1.7	180	815	310

Lot I, fed 4.4 lbs. caddo cake containing 28.9 per ct. crude protein, made slightly larger gains than Lot II, fed 3.1 lbs. choice cottonseed meal containing 42.9 per ct. crude protein. In feed required per 100 lbs. gain, 133 lbs. of caddo cake was more than equal to 100 lbs. of cottonseed meal, a somewhat higher value than would correspond to the amounts of crude protein in the 2 feeds. Kinzer states that in a trial at the Kansas Station[39] steers fed caddo cake likewise made slightly larger gains than others fed cottonseed meal, and Smith reports from trials at the Nebraska Station[40] that cattle relish caddo cake even better than cottonseed meal. (**248**)

752. Cotton seed.—The practice of feeding cotton seed to beef cattle in the South is rapidly declining according to Soule of the Georgia Station,[41] both because of the demand for the seed for oil production and because cottonseed meal gives uniformly better results than the whole

[35] Miss. Bul. 121.
[36] Ala. Bul. 158.
[37] Breeder's Gaz., 59, 1911, p. 1163.
[38] Breeder's Gaz., 58, 1910, p. 303.
[39] Breeder's Gaz., 58, 1910, p. 350.
[40] Nebr. Bul. 116.
[41] Breeder's Gaz., 66, 1914, p. 713.

seed. In a 90-day trial at the Texas Station[42] Burns fed 2 lots, each of 6 high-grade Angus steers, 16.0 lbs. of kafir chop and 12.8 lbs. of cottonseed hulls per head daily with the allowance of cottonseed meal or meal and cotton seed shown in the table:

Cotton seed vs. cottonseed meal for fattening steers

Cottonseed meal and cotton seed per head daily	Daily gain	Feed for 100 lbs. gain	
		Concentrates	Hulls
	Lbs.	Lbs.	Lbs.
I, Cottonseed 4.0 lbs. Cottonseed meal, 1.0 lb. ..	2.0	1,026	626
II, Cottonseed meal, 2.9 lbs.	2.5	750	508

Substituting 4 lbs. of cotton seed for 1.9 lbs. of cottonseed meal produced smaller gains. In this trial cottonseed meal at $26 per ton was cheaper than cotton seed at $12. In a later trial with steers fed sorghum and cowpea silage, Burns[43] found that when the allowance of cotton seed was increased beyond 8 lbs. per head daily the animals scoured badly; on substituting cottonseed meal for the cotton seed they recovered and made much larger gains. Cottonseed meal at $27 per ton was more profitable than cotton seed at $17. **(245)**

753. Linseed meal.—Thruout the northern states linseed meal is widely used as a nitrogenous supplement for beef cattle. Smith of the Nebraska Station,[44] as a result of 3 trials with steers, fed corn and prairie hay, in comparison with others fed 90 per ct. corn and 10 per ct. linseed meal with prairie hay, found that it required 23 per ct. less concentrates for 100 lbs. gain when the ration containing linseed oil meal was used. For steer fattening linseed meal was slightly superior to cottonseed meal, and much more valuable than wheat bran for supplementing a ration of corn and prairie hay or corn stover. As a supplement to corn and prairie hay, in 2 trials[45] with yearling steers linseed meal was worth $29.74 to $32.00 per ton, compared with cold-pressed cottonseed cake at $25. **(254)**

754. Soybeans.—The protein-rich seed of the soybean is well suited to serve as a nitrogenous supplement for fattening cattle. To compare this concentrate and choice cottonseed meal, Skinner and King conducted 2 trials at the Indiana Station[46] with 900-lb. steers, fed the following rations for 180 and 175 days, respectively:

Ground soybeans vs. cottonseed meal for fattening steers

Average ration	Daily gain	Feed for 100 lbs. gain		
		Concentrates	Straw	Silage
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I				
Shelled corn, 13.0 lbs. Oat straw, 1.1 lbs. Ground soybeans 2.7 lbs. Corn silage, 22.1 lbs.	2.2	722	52	1,011
Lot II				
Shelled corn, 13.9 lbs. Oat straw, 0.9 lb. Cottonseed meal, 2.8 lbs. Corn silage, 26.3 lbs.	2.5	676	36	1,062

[42] Tex. Bul. 110.
[43] Tex. Bul. 159.
[44] Nebr. Bul. 100.
[45] Nebr. Bul. 132.
[46] Ind. Buls. 167, 178.

While Lot II made somewhat larger gains and required slightly less feed per 100 lbs. gain, the results from Lot I, fed ground soybeans, were on the whole satisfactory. The steers showed a greater tendency to go off feed during the last 3 months of the feeding period on soybeans than on cottonseed meal, due undoubtedly to the large amount of oil that soybeans contain. With soybean meal, from which the oil has been extracted, this condition would probably not result. In a third trial[47] lasting 150 days, steers fed the same ration as Lot I made slightly larger gains than lots fed cottonseed meal, shelled corn, corn silage, and either clover or alfalfa hay. (**256**)

755. Soybeans, cowpeas, and corn.—In the southern states it is possible to grow a winter crop of small grain and harvest it in time to plant soybeans, cowpeas, or corn, thus securing 2 crops each year from the same land. During 7 years the following crops have been grown on different acres at the Tennessee Station[48] by Quereau and Willson and fed to steers, to determine the amount of beef produced per acre under the different systems of cropping. In addition to the product from the given acre, the steers were each fed 20 lbs. of corn silage per head daily. The manure resulting from the crops on each acre was returned thereto.

Acre yields of beef from various crops in the South

Crops and acre yield	Beef per acre Lbs.	Crops and acre yield	Beef per acre Lbs.
Acre I		*Acre IV**	
Soybean grain, 1,189 lbs.		Soybean grain, 1,202 lbs.	
Soybean stover, 2,877 lbs.		Soybean stover, 2,552 lbs.	
Barley grain, 1,411 lbs.	508	Wheat grain, 1,216 lbs.	402
Acre II		*Acre V†*	
Cowpea grain, 550 lbs.		Soybean hay, 3,727 lbs.	
Cowpea stover, 2,104 lbs.		Barley grain, 1,443 lbs.	435
Barley grain, 1,656 lbs.	451		
		*Acre VI**	
Acre III		Soybean hay, 3,376 lbs.	
Corn grain, 1,839 lbs.		Oat grain, 1,610 lbs.	456
Corn stover, 3,045 lbs.			
Barley grain, 1,332 lbs.	434	*Acre VII‡*	
		Alfalfa hay, 8,228 lbs.	515

*Av. for 4 years. †Av. for 6 years. ‡Av. for 5 years.

Of the various combination crops, Acre I, on which soybeans were grown for grain and stover, with barley as a winter grain crop, produced the largest amount of beef per acre. Cowpeas yielded much less grain and stover and produced less beef per acre. Acre III, on which were grown corn for grain and stover, with barley as the winter crop, made considerably less beef per acre than Acre I, due in no small measure to the unbalanced nature of the ration of corn grain, corn stover, corn silage, and barley grain. Alfalfa, tested for 5 years, slightly surpassed even Acre I. The returns from these acres well illustrate the possibilities of the South for beef production in a system whereby more than a single crop is grown each year. (**262**)

[47] Information to the authors. [48] Information to the authors.

756. Wheat bran.—Since wheat bran is lower in protein than cottonseed or linseed meal, a correspondingly larger amount is needed to balance a ration deficient in this nutrient. While bran is used more extensively for dairy cows than for feeding beef cattle it is often employed for the latter, especially in starting cattle on feed. Skinner and Cochel[49] found in replies from 929 Indiana cattle feeders, secured in 1906, that 40 per ct. of those using some supplement to corn preferred bran, doubtless because it was available in almost every locality. In 4 trials at the Nebraska Station[50] Smith found that when fed as a supplement to corn and prairie hay, corn stover, or corn silage, bran produced somewhat smaller gains than linseed meal, cottonseed meal, or cold-pressed cottonseed cake and the gains were more expensive.

In 2 trials at the Pennsylvania Station[51] by Tomhave, Hickman, and Severson the common Pennsylvania ration of wheat bran, corn, mixed hay and corn stover proved inferior to one of corn, cottonseed meal, mixed hay, and corn silage, undoubtedly due in large part to the substitution of silage for the stover. **(218)**

757. Gluten feed.—Tho most commonly fed to dairy cows, gluten feed is a satisfactory nitrogenous concentrate for fattening cattle. In trials at the Missouri Station[52] in which the value of various supplements to corn for steers of various ages on good bluegrass pasture was compared, Mumford found that steers fed linseed or cottonseed meal and corn generally made slightly larger gains than others fed gluten feed and corn. **(210)**

758. Dried distillers' grains; distillery slop.—That a limited allowance of dried distillers' grains is satisfactory for fattening cattle is shown in a trial by May at the Kentucky Station[53] with 2 lots, each of 4 steers, running on closely cropped bluegrass pasture, and fed an unlimited allowance of clover hay. Lot I, fed 14.3 lbs. of corn-and-cob meal and 5.4 lbs. of dried distillers' grains per head daily, made 2.2 lbs. average daily gain, and required 882 lbs. of concentrates per 100 lbs. gain. Lot II, fed a daily allowance of 23.0 lbs. corn-and-cob meal, gained only 1.8 lbs. daily per head and required about 400 lbs. more concentrates per 100 lbs. gain. **(282)**

In the vicinity of distilleries many cattle are fattened on the wet distillery slop or mash. Hooper of the Kentucky Station[54] reports that in 1911 about 25,000 steers were so fed in Kentucky. The slop is pumped from the distillery to the feed lots, where it is fed in troughs. In addition to the slop an average of about 3 lbs. of cottonseed meal is fed per head daily, with 10 to 15 lbs. of hay, straw, bluegrass chaff, or cottonseed hulls. The roughage and the cottonseed meal are usually mixed with the slop, tho sometimes the steers are permitted to drink the clear slop.

[49] Ind. Cir. 12.
[50] Nebr. Buls. 100, 132.
[51] Penn. Bul. 133; information to the authors.
[52] Mo. Bul. 90.
[53] Ky. Bul. 108.
[54] Ky. Sta. Miscel. Circular.

759. Dried brewers' grains.—According to Pott,[55] in Germany dried brewers' grains are well esteemed as a concentrate for fattening mature cattle, meat of especially good quality being produced on dried brewers' grains, fed as the sole concentrate with potatoes, beets, and dry roughage. (228)

760. Velvet bean.—At the Florida Station[56] Scott fed velvet beans in the pod in comparison with other feeds to sixteen 700-lb. steers divided into 4 lots of 4 each, for 84 days, with the results shown in the table:

Velvet beans compared with other southern feeds for steers

Average ration per 1,000 lbs. of steer		Av. daily gain Lbs.	Feed cost of 100 lbs. gain Dollars
Lot I			
Corn, 8.0 lbs.			
Velvet beans in pod, 12.0 lbs.	Cottonseed hulls, 10.0 lbs......	2.9	7.55
Lot II			
Corn, 10.5 lbs.			
Cottonseed meal, 3.8 lbs.	Crab-grass hay, 13.5 lbs..	2.6	9.07
Lot III			
Corn, 6.0 lbs.	Cottonseed hulls, 14.0 lbs.		
Cottonseed meal, 5.0 lbs.	Sorghum silage, 20.0 lbs........	2.7	10.65
Lot IV			
Cottonseed meal, 6.5 lbs.	Cottonseed hulls, 25.0 lbs........	1.9	12.00

It is shown that the steers getting 12 lbs. of velvet beans in the pod per 1,000 lbs. of live weight, together with corn and cottonseed hulls, made the high average gain of 2.9 lbs. daily for 84 days. While all gains were satisfactory, those of the steers fed velvet beans were the largest and cheapest. (361)

III. Legume Hay and Other Dry Roughages

761. Value of legume hay.—The great importance of hay from the legumes in balancing the carbonaceous grains, such as corn, barley, and wheat, has already been pointed out. (732) On account of their richness in protein and also because of their palatability, the legume hays are the most valuable of dry roughages. Even when a ration of corn and such carbonaceous roughages as timothy hay, prairie hay, or corn fodder is properly supplemented by linseed or cottonseed meal or some other protein-rich concentrate, smaller gains will nearly always be produced than when the ration consists of corn and legume hay. This is shown in the following table, which summarizes the results secured in 4 trials in which 2-yr.-old 942-lb. steers were fed for periods averaging 158 days:

[55] Handb. Ernähr. u. Futter., II, 1909, p. 241.
[56] Fla. Bul. 102.

Legume hay vs. carbonaceous roughage plus nitrogenous supplement

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Roughage Lbs.
*Lot I, total of 40 steers**			
Legume hay, 9.3 lbs. Corn, 17.9 lbs.	2.3	778	405
*Lot II, total of 42 steers**			
Carbonaceous roughage 8.0 lbs. Corn, 16.4 lbs. Supplement, 2.2 lbs.	2.0	916	387

*Av. of 1 trial by Bliss and Lee (Nebr. Bul. 151), 1 by Mumford (Ill. Bul. 83), 1 by Skinner and Cochel (Ind. Bul. 115), and 1 by Smith (Nebr. Bul. 90).

Lot I, fed legume hay and corn, gained on the average 0.3 lb. more per head daily and required 15.1 per ct. less concentrates and about the same amount of roughage as Lot II, fed the equally well-balanced but less palatable ration in which the roughage was prairie hay, timothy hay, or corn stover with a small amount of oat straw. Only when silage, appetizing as well as nutritious, is fed is it possible to provide a ration which will be equal to one where the roughage is legume hay. **(775)**

Waters[57] points out that where cattle are being fattened on corn, the use of legume hay instead of hay from timothy, millet, or sorghum, or such roughages as corn stover and straw, results in the following advantages:

1. Increased gains by the cattle.
2. Increased selling price of the cattle due to extra bloom.
3. Increased gains by hogs following the steers.
4. Increased fertility of the land where the feeding operations are conducted.
5. The better condition of the fields on which the leguminous crops are grown.

762. Legume hay plus carbonaceous roughage.—Even on farms where large areas of legumes are raised for hay much carbonaceous roughage, such as corn and sorghum stover, straw, and hay from the grasses, is normally produced in addition. In economical beef production these roughages should be wisely and fully utilized, for while they do not equal legume hay in nutrients or palatability, when judiciously combined with it satisfactory and cheap gains may be secured. This is shown in a 116-day trial by Snyder at the North Platte, Nebraska, Substation[58] in which 5 lots, each of 20 good grade steer calves averaging about 425 lbs., were wintered on 2 lbs. of a mixture of 2 parts corn and 1 part oats, with the roughages shown in the table:

Value of legume hay combined with carbonaceous roughages

Average daily roughage allowance	Av. daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Roughage Lbs.
Lot I, Alfalfa hay, 12.3 lbs.	1.2	162	1,000
Lot II, Sorghum hay, 14.3 lbs.	0.4	504	3,666
Lot III, Alf. hay, 8.5 lbs. Sorghum hay, 8.5 lbs.	1.2	165	1,416
Lot IV, Prairie hay, 10.9 lbs.	0.7	305	1,676
Lot V, Alfalfa hay, 7.5 lbs. Prairie hay, 7.5 lbs.	1.1	174	1,315

[57]Mo. Bul. 76. [58]Nebr. Bul. 105.

When fed as the only roughage sorghum hay produced unsatisfactory gains, but when the roughage allowance was half sorghum and half alfalfa, the gains were as rapid as those made by Lot I, fed alfalfa only. Likewise Lot IV, fed prairie hay, made much poorer gains than Lot I, while Lot V, fed half prairie hay and half alfalfa made satisfactory gains for calves being carried over winter. In all cases the gains on the rations containing alfalfa were made with a surprisingly small amount of feed.

The good results from combining legume hay with carbonaceous roughage are further shown in a trial by Waters at the Missouri Station.[59] Two-yr.-old steers fed timothy hay and corn made much smaller gains than those fed clover hay and corn. However, on clover hay, corn stover, and corn, as large gains were produced as when clover hay was the sole roughage.

Smith[60] reports that cattle full fed on corn with alfalfa as the only roughage are more subject to scours, which cause them to go off feed, than when some such carbonaceous roughage as prairie hay, sorghum hay, or corn stover is fed with the alfalfa.

763. Legume hay with cottonseed meal.—Since legume hay is rich in protein it should not be fed as the chief roughage with cottonseed meal, which is itself so rich in this nutrient. Craig and Marshall found in trials at the Texas Station[61] that steers fed 5 lbs. of cottonseed meal and 2.8 lbs. rice bran per head daily with peanut hay developed looseness of the bowels and showed redness of the eyes and some swelling about the sheath; when changed to prairie hay the unfavorable symptoms disappeared and the gains increased. Similar poor results were secured when alfalfa hay was fed with cottonseed meal. When shelled corn was substituted for a part of the cottonseed meal, gains became normal. Legume hay serves its highest purpose when combined with such carbonaceous concentrates as corn, kafir, and milo. Where cottonseed meal is the chief concentrate leguminous roughages should be fed in limited amount, at most, along with such carbohydrate-rich roughages as forage from corn or the sorghums, or cottonseed hulls.

764. Clover hay.—The value of this standard roughage of the eastern corn belt compared with timothy hay, when both are fed with corn, is shown in the following table. This summarizes the results of a 180-day trial by Skinner and Cochel at the Indiana Station[62] and a 105-day trial by Waters at the Missouri Station,[63] both with 2-yr.-old steers:

Clover hay and shelled corn compared with timothy hay and shelled corn

Average ration		Daily gain	Feed for 100 lbs. gain Corn	Hay
		Lbs.	Lbs.	Lbs.
Lot I, Clover hay, 9.8 lbs.	Shelled corn, 21.5 lbs....	2.4	919	416
Lot II, Timothy hay, 6.4 lbs.	Shelled corn, 18.8 lbs	1.8	1,086	380

[59]Mo. Bul. 76.
[60]Nebr. Bul. 116.
[61]Tex. Bul. 76.
[62]Ind. Bul. 129.
[63]Mo. Bul. 76.

In both trials the clover-fed lot ate more grain and roughage than Lot II, fed timothy, and made larger and more economical gains, requiring about 15.4 per ct. less corn for a given increase. Skinner and Cochel report that thruout the experiment the clover-fed steers were in better condition, had better appetites, and were more regular feeders. The timothy-fed steers were irregular in their appetites, and even when eating a full feed seemed unsatisfied. At the close of the 6-months feeding period the average weight of the clover-fed steers was 1,373 lbs., and that of the timothy-fed steers 1,281 lbs. Waters found that corn was worth about 8 cents per bushel more when fed with clover or cowpea hay to fattening steers than when fed with timothy hay. **(312, 347)**

765. Clover vs. alfalfa hay.—In 2 trials at the Indiana Station[64] Skinner and King compared the value of clover and alfalfa hay when fed either with shelled corn and 2.5 lbs. of cottonseed meal daily per 1,000 lbs. live weight or with the same feeds and an unlimited amount of corn silage. When fed without silage, clover hay made slightly larger gains and with slightly less feed per 100 lbs. gain than alfalfa hay. With corn silage, the results were reversed. We may therefore conclude that these hays have about equal value when fed in such rations. It should be pointed out, however, that all of these rations contained sufficient cottonseed meal to balance the ration fairly well without the legume hay. Since alfalfa hay is considerably richer than clover hay in protein, it is reasonable to hold that it is more efficient than clover in balancing a ration deficient in this nutrient. This view is substantiated in a trial by Wilson at the South Dakota Station[65] in which yearling steers fed only alfalfa hay and corn silage during the first 91 days of the fattening period gained 2.5 lbs. per head daily, while others fed clover hay and silage gained only 2.3 lbs. and required more feed per 100 lbs. of gain.

766. Alfalfa hay as a nitrogenous supplement.—The value of alfalfa hay as a supplement to rations low in protein is shown in a series of 5 trials by Bliss at the Nebraska Station.[66] Yearlings or 2-yr.-old steers were fed rations of corn and carbonaceous roughage (prairie hay, corn stover, or corn silage) to which were added quantities of alfalfa hay, linseed meal, cottonseed meal, and cold-pressed cottonseed cake, supplying approximately equal amounts of protein. In these trials the lots fed alfalfa hay as the sole nitrogenous supplement made, on the average, the largest gains and reached the best finish, a fact of great importance to the corn-belt farmer who can grow this legume. **(339)**

767. Alfalfa with and without silage.—The results of 4 trials in which a ration of alfalfa hay and corn has been compared with one of alfalfa hay, corn silage, and corn are summarized in the following table. In these trials 2-yr.-old steers averaging 945 lbs. were fed for periods ranging from 150 to 157 days.

[64]Ind. Bul. 178; information to the authors.
[65]S. D. Bul. 160.
[66]Nebr. Buls. 100, 116, 132.

Alfalfa with and without silage for fattening steers

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Hay Lbs.	Silage Lbs.
Lot I, total of 30 steers*				
Alfalfa hay, 8.3 lbs. Corn, 16.4 lbs.†	2.1	770	391	....
Lot II, total of 49 steers*				
Alfalfa hay, 3.9 lbs.				
Corn silage, 20.6 lbs. Corn, 14.7 lbs.†	1.9	761	200	1,070

*Average of 2 trials by Bliss and Lee (Nebr. Bul. 151), 1 by Lee at the Nebr. Station (Information to the authors), and 1 by Rusk at the Ill. Station (Breeder's Gaz., 61, 1912, p. 1041).
† Broken ear corn fed in Illinois trial reduced to shelled corn equivalent.

The addition of corn silage to the excellent ration of alfalfa hay and corn decreased rather than increased the gains. We might suppose that this was due to Lot II not eating sufficient alfalfa to balance their ration. However, at both the Nebraska and the Illinois Stations adding cottonseed meal or cake to the ration fed Lot II, brought no larger gains. The relative economy of the rations fed Lot I and Lot II will depend on the cost of alfalfa and silage. In the Nebraska trials the cheaper gains were produced without silage. On the other hand, Rusk concludes that in Illinois the larger the proportion of silage to alfalfa, the cheaper will be the gain.

768. Fattening cattle on alfalfa and other roughage.—In some sections of the West where alfalfa is abundant and the market does not pay a higher price for a well finished animal than for one in only fair flesh, cattle are fed on alfalfa alone or alfalfa and other roughages without concentrates, when they are not marketed directly from the range. To determine whether it would be profitable to feed a limited allowance of corn in addition to alfalfa, either thruout the feeding period or for the last part only, Simpson fed yearling range steers as shown below for 90 days at the New Mexico Station.[67]

Alfalfa alone, vs. alfalfa and corn stover, vs. alfalfa and corn

	Daily gain Lbs.	Feed cost per 100 lbs. gain Dollars
Alfalfa alone	1.84	3.92
Alfalfa plus corn stover	1.17	4.01
Alfalfa plus 8 lbs. corn meal per day	2.58	7.33
Alfalfa plus corn during last 30 days	2.06	5.55

The steers fed alfalfa alone made larger gains than those fed alfalfa and corn stover, and were in much better condition at the end of the trial. Those fed corn, either thruout the trial or during only the last month made better gains than those fed hay alone, but under New Mexico conditions the gains were much more expensive, with corn at $35 and alfalfa hay at $10 per ton. In a trial by Vernon and Scott at the same Station[68] 2-yr.-old range steers averaging 550 lbs. gained 1.7

[67] N. Mex. Rpt. 21, p. 32. [68] N. Mex. Bul. 57.

lbs. per head daily on alfalfa hay alone, making a total gain of 205 lbs. per steer, and requiring only 1,100 lbs. of alfalfa hay per 100 lbs. of gain. This shows the marked economy of alfalfa for feeding steers for the local markets in the western alfalfa districts.

True and McConnell of the Arizona Station,[69] after 6 feeding trials, conclude that, where no concentrates are fed, alfalfa hay alone is about equal in feeding value to alfalfa hay combined with such carbonaceous roughages as corn, kafir, and sweet sorghum. Where water is abundant alfalfa hay is cheaper than the other roughages, but where it is in scant supply or the soil is excessively alkaline, kafir and the sweet sorghums form economical roughages in combination with alfalfa.

769. Sweet clover hay; cowpea hay.—When fed with corn silage and without concentrates to yearling steers during the first 91 days of fattening, Wilson of the South Dakota Station[70] found sweet clover hay practically equal to alfalfa hay. The steers in both lots made average daily gains of over 2.4 lbs. Some difficulty was experienced in getting the steers to eat the sweet clover hay until it was run thru a hay cutter. **(352)**

Waters found cowpea hay fully equal to clover hay when fed with shelled corn in a trial at the Missouri Station[71] in which 2-yr.-old steers were fed for 105 days, the average daily gain for both lots being 2.7 lbs. **(357)**

770. Grazing cowpeas and corn.—Bennett of the Arkansas Station[72] sowed cowpeas in a five-acre corn field. In October, after gathering the corn, steers were turned into a portion of the field to graze on the corn forage and cowpeas, with cotton seed accessible. When one-third of the field was grazed off, another portion was set aside, and so on until it was all grazed over. Six steers averaging 770 lbs. when turned into the field made an average daily gain of 2 lbs. each for 64 days, consuming 250 lbs. of cotton seed in that time, besides corn forage and pea vines with pods. Bennett states that allowing for all expenses the gains made by the steers cost but $1.60 per 100 lbs. Such practice tends to soil improvement as well as cheap meat production.

771. Corn fodder or shock corn; stover.—It has already been pointed out that shock corn is often the most economical way to supply corn to fattening steers, especially during the first part of the fattening period. **(735)** As is shown later, fattening cattle fed bright corn fodder with legume hay, may make practically as large gains as those fed silage. **(781)** The economy of feeding silage lies in the smaller amount of feed required per 100 lbs. gain. **(295, 302)**

The value of corn stover when combined with legume hay is shown in 2 trials by Smith at the Nebraska Station[73] in which lots of ten 2-yr.-old range steers, averaging 957 lbs., were fed the following rations:

[69] Ariz. Bul. 50.
[70] S. D. Bul. 160.
[71] Mo. Bul. 76.
[72] Ark. Rpt. 1899.
[73] Nebr. Buls. 90, 93, 100.

Corn stover fed in combination with alfalfa hay to fattening steers

Average ration		Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Roughage Lbs.
Trial lasting 84 days				
Lot I, Alfalfa hay, 22.2 lbs.	Corn, 9.5 lbs.	2.1	460	1,075
Lot II, Corn stover, 11.2 lbs. Alfalfa hay, 11.2 lbs.	Corn, 9.6 lbs.	2.0	490	1,144
Trial lasting 168 days				
Lot I, Alfalfa hay, 9.2 lbs.	Corn, 18.6 lbs.	2.3	814	402
Lot II, Alfalfa hay, 4.9 lbs. Corn stover, 4.9 lbs.	Corn, 18.4 lbs.	2.4	789	456

Replacing half the alfalfa hay by corn stover did not affect the rate of gain in these trials. Thru thus combining such cheap roughage as corn stover with legume hay the cost of beef production may often be materially lowered. In these trials there is brought out incidentally the interesting fact that the short-fed steers required less than 500 lbs. of corn for 100 lbs. of gain, while the long-fed steers, which were of course much better fattened, required 800 lbs. of corn for 100 lbs. of gain—69 per ct. more than the short-fed steers. **(715)**

772. Roughages for the plains district.—In the semi-arid districts fodder and stover from the sorghums, both sweet sorghum and the grain sorghums, are most useful feeds in beef production, when fed with legume hay or with a sufficient amount of nitrogenous concentrates to balance the ration. At the Hays, Kansas, Station[74] Cochel wintered 4 lots each of 25 yearling heifers, averaging 667 lbs., on the following roughages with 1 lb. of linseed meal per head daily:

Wintering yearling heifers in western Kansas

Average roughage allowance	Daily gain Lbs.	Cost per head daily* Cents
I, Kafir stover, 12.9 lbs. Silage, 10 lbs. Straw, 2.6 lbs.	0.69	5.8
II, Sorghum stover, 6.6 lbs. Silage, 10 lbs. Straw, 2.6 lbs.	0.67	5.7
III, Sudan hay, 7.5 lbs. Silage, 10 lbs. Straw, 2.6 lbs.	0.67	5.7
IV, Alfalfa hay, 8.2 lbs. Silage, 10 lbs. Straw, 2.6 lbs.	0.66	6.3

*Kafir and sorghum stover, $3, Sudan hay, $5, damaged alfalfa hay, $6, silage, $3, straw, $0.50, and linseed meal, $30.80 per ton.

These heifers were carried thru the winter, making satisfactory gains to put them into condition to make good use of pasture the next summer, at a surprisingly low cost. (The figures given include expenses for both feed and labor.) The alfalfa hay had been damaged and was therefore not marketable. This trial well shows the possibilities in beef production, where wise use is made of by-product roughages which would be wasted in a system of grain farming. **(308)**

773. Cottonseed hulls.—For many years the standard ration for fattening cattle in the South was cottonseed meal and cottonseed hulls. This combination has been compared with a ration of cottonseed meal

[74]Kansas Industrialist, May 1, 1915.

and corn silage in 8 trials averaging 110 days, at 4 different stations, with the results summarized in the table:

Cottonseed hulls vs. corn silage for fattening steers

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Cottonseed meal Lbs.	Feed for 100 lbs. gain Hulls or silage Lbs.	Feed cost of 100 lbs. gain Dollars
*Lot I, total of 121 steers**					
Cottonseed hulls, 25.2 lbs.					
Cottonseed meal, 6.9 lbs....	924	1.5	466	1,690	12.78
*Lot II, total of 111 steers**					
Corn silage, 42.0 lbs.					
Cottonseed meal, 6.9 lbs....	927	1.7	439	2,574	10.72

*Average of 4 trials by Curtis (N. C. Buls. 199, 218, 222), 1 by Lloyd (Miss. Station, information to the authors), 1 by Smith (S. C. Bul. 169), and 2 by Willson (Tenn. Bul. 104).

In these trials the steers fed silage usually made slightly larger gains than those receiving hulls, but the chief difference was that with a single exception the silage-fed lot made by far the cheaper gains. As has already been shown **(750)**, the longer the feeding period, the greater is the superiority of silage over hulls. In these trials the silage-fed steers almost uniformly showed better finish and better handling quality than those fed hulls. Willson points out that cottonseed hulls are so successfully fed that there is a tendency on the part of many southern farmers to purchase hulls and allow more valuable roughage to waste on the farms.

Willson reports that when 6 lbs. of hulls were given per head daily with corn silage to steers fed cottonseed meal, slightly larger gains were produced than with corn silage as the sole roughage. On the other hand, in 3 trials at the North Carolina Station[75] Curtis found that on the average steers fed corn silage as the sole roughage with 7.5 lbs. of cottonseed meal per head daily made slightly larger gains than others fed corn stover in addition to corn silage and the same allowance of cottonseed meal. Whether silage should be fed as the sole roughage with cottonseed meal will therefore depend on the price at which dry roughages are available. Silage from sweet sorghum or the grain sorghums is but little inferior to corn silage as a roughage for steers fed cottonseed meal. **(782)** Compared with other dry roughages cottonseed hulls are exceedingly well suited to feed with cottonseed meal. Gray and Ward[76] found in an Alabama trial with 855-lb. steers that when fed with cottonseed meal cottonseed hulls produced better gains than a combination of Johnson grass hay and cottonseed hulls. Duggar and Ward[77] report that 2-yr.-old steers fed cottonseed meal and hulls made larger gains than others fed cottonseed meal with either shredded corn stover or cut sorghum hay. At the Texas Station[78] Craig found that yearling steers fed cottonseed meal and hulls made nearly as large gains as those fed corn-and-cob meal and alfalfa hay. **(251)**

[75]N. C. Bul. 222.
[76]U. S. Dept. Agr., Bur. Anim. Indus., Bul. 159.
[77]Ala. Bul. 103.
[78]Tex. Bul. 76.

In a 119-day trial with 1230-lb. steers at the Kentucky Station[79] Good found that slightly larger gains were produced on a ration of 21.3 lbs. broken ear corn, 3.5 lbs. cottonseed meal, 4.7 lbs. cottonseed hulls, and 4.3 lbs. clover hay than when the steers were fed the same feeds and all the corn silage they would consume. The silage ration, however, produced the cheaper gains, and returned a greater profit. The great value and usefulness of corn silage in combination with cottonseed meal for fattening cattle, as demonstrated by the experiment stations of the South, should greatly stimulate cattle rearing and fattening in the cotton belt.

III. Succulent Feeds

774. Importance of silage in beef production.—The use of silage is fast revolutionizing the feeding of beef cattle, just as it has the feeding of milch cows in the leading dairy sections of our country. Wherever either corn or the sorghums thrive, silage from these crops, cut when well matured, has proven of great value in cheapening the cost of beef production. (**411**) As is shown later (**788-90**), breeding cows and stock cattle may be maintained in winter in good condition on silage from well-matured corn or the sorghums, with a limited amount of legume hay or a small allowance of such nitrogenous concentrates as cottonseed or linseed meal. For growing animals this palatable succulence can not be excelled, when fed in proper combination with legume hay or concentrates rich in protein. (**798-9**)

On well-balanced rations in which silage is the chief roughage the steer will fatten rapidly and reach a high finish on a moderate allowance of expensive concentrates. By feeding, during the first stages of fattening, only silage and either legume hay or a small allowance of some nitrogenous concentrate to balance the ration, the feed cost of the gains may usually be still further reduced. At first it was thought that silage-fed cattle shrank more in shipment than those finished on dry roughage. Trials have now abundantly demonstrated, however, that if silage is withheld for the last day or two before shipment and dry roughage fed instead, cattle thus fattened will not shrink any more than those receiving no silage.

775. Corn silage.—Silage from well-matured corn, carrying an abundance of ears, is the best of all silage for beef cattle. (**300-4**) Such silage carries a high proportion of grain and aids materially in reducing the amount of concentrates which need be supplied in addition. Many experienced cattle feeders prefer silage from corn which is even more mature than the stage at which it is usually cut for dairy cattle. When the corn is cut when nearly mature, especial care must be taken in tramping the silage, or it may mold. To show the good results from feeding corn silage there are summarized in the following table the results of 10 trials where corn silage was added to the already excellent ration of

[79]Information to the authors.

shelled corn, cottonseed or linseed meal, and clover or alfalfa hay. In these trials 2-yr.-old steers averaging 1,006 lbs. in weight were fed for an average of 162 days.

Value of corn silage when added to an already excellent ration

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Hay Lbs.	Silage Lbs.	Feed cost of 100 lbs. gain Dollars
*Lot I, total of 105 steers**					
Legume hay, 10.7 lbs.					
Shelled corn, 18.0 lbs.					
Supplement, 2.8 lbs.	2.47	849	435	...	11.56
*Lot II, total of 105 steers**					
Corn silage, 23.6 lbs.					
Legume hay, 3.8 lbs.					
Shelled corn, 15.0 lbs.					
Supplement, 2.9 lbs.	2.51	716	152	952	10.18

*Average of 8 trials by Skinner, Cochel, and King (Ind. Buls. 129, 136, 153, 163, 167, 178, and information to the authors), 1 by Allison (Mo. Bul. 112), and 1 by Evvard at the Iowa Station (Breeder's Gaz., 61, 1912, p. 1040).

The steers in Lot II, given a heavy allowance of silage, consumed 23.6 lbs. per head daily and ate 3 lbs. less corn and 6.9 lbs. less legume hay than those in Lot I. The silage ration did not produce appreciably larger gains than did legume hay fed as the sole roughage. The principal advantage from feeding silage is shown in the feed required per 100 lbs. gain and in the feed cost of the gains. The 952 lbs. of silage eaten by Lot II per 100 lbs. gain saved 133 lbs. of concentrates and 283 lbs. of legume hay, or about 16 per ct. of the concentrates and 65 per ct. of the hay eaten by Lot I. Substituting silage for this amount of concentrates and hay reduced the feed cost of the gains $1.38 per 100 lbs., a sum which would often make the difference between feeding at a loss and making a goodly profit. The silage-fed steers were slightly better finished on the average and sold for 3 cents more per 100 lbs. than those fed no silage.

776. Feeding a supplement with unlimited silage allowance.—We have seen that a ration of corn and legume hay is fairly well balanced and that the addition of a nitrogenous concentrate does not greatly increase the rate of gain with 2-yr.-old steers. (**733**) When steers are allowed an unlimited allowance of silage in addition to corn and legume hay, owing to the great palatability of the silage they will generally eat but 3 to 6 lbs. of hay per head daily, while they will eat 25 to 30 lbs. of corn silage during the first weeks of fattening, and gradually less as fattening progresses. To determine whether this small amount of clover hay is sufficient to balance the large quantity of corn and corn silage consumed, Skinner and Cochel conducted 2 trials at the Indiana Station[80] and Allison 1 at the Missouri Station[81] with 2-yr.-old, 1035-lb. steers fed for an average of 153 days.

[80] Ind. Bul. 129.

[81] Mo. Bul. 112.

Adding a nitrogenous supplement to corn, corn silage, and clover hay

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Hay Lbs.	Silage Lbs.	Feed cost of 100 lbs. gain Dollars
Lot I					
Shelled corn, 16.7 lbs.					
Corn silage, 17.0 lbs.					
Clover hay, 4.2 lbs........	2.0	852	215	855	9.05
Lot II					
Nitrogenous supplement, 2.8 lbs.					
Shelled corn, 17.3 lbs.					
Corn silage, 17.3 lbs.					
Clover hay, 4.2 lbs........	2.8	722	151	610	7.95

The steers in Lot II, fed 2.8 lbs. of nitrogenous supplement (cottonseed or linseed meal) in addition to shelled corn, corn silage, and clover hay, gained 0.8 lb. more per head daily than Lot I, receiving no supplement. The feed cost of 100 lbs. gain for Lot II was $1.10 lower than for Lot I, and furthermore Lot II sold for 30 cents per 100 lbs. more on account of better finish. The nutritive ratio of the rations fed Lot I in these trials was 1:9 or wider, while with Lot II it was 1:7 or narrower. These trials hence indicate that for the most rapid fattening the 2-yr.-old steer should receive a narrower nutritive ratio than 1:9.

There appears to be less advantage in adding a nitrogenous concentrate to a ration of corn, corn silage, and alfalfa hay, doubtless due to the richness of this hay in protein. Bliss and Lee have studied this problem in 2 trials at the Nebraska Station[82] and Rusk in 1 trial at the Illinois Station.[83] In no trial did the addition of a supplement (cottonseed meal or cold-pressed cake) increase the gains. The use of the supplement did, however, result in better finish and a consequent higher selling price. When a carbonaceous roughage, such as prairie or timothy hay, corn or kafir fodder, or straw, is fed with corn and corn silage the need of a nitrogenous supplement will be greater than when clover hay is used.

777. Amount of nitrogenous supplement with silage.—To determine how much cottonseed meal should be given to 2-yr.-old steers full fed on shelled corn, corn silage and clover hay, Skinner and King fed one lot of 10 steers 2.5 lbs. of cottonseed meal daily per 1,000 lbs. live weight and another lot 1.25 lbs. daily in 2 trials at the Indiana Station,[84] lasting 150 and 160 days. Two similar trials lasting 175 and 180 days, were conducted[85] to determine whether it was more profitable to feed 2.5 or 4.0 lbs. of cottonseed meal daily per 1,000 lbs. live weight to steers fed shelled corn, corn silage, and oat straw, with the results shown in the table:

[82]Nebr. Bul. 151 and information to the authors.
[83]Breeder's Gaz., 61, 1912, p. 1041.
[84]Ind. Bul. 153.
[85]Ind. Buls. 167, 178.

Amount of cottonseed meal to feed with corn and corn silage

Daily allowance of cottonseed meal per 1,000 lbs. live weight	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Dry roughage Lbs.	Silage Lbs.	Nutritive ratio
With clover hay and silage						
Lot I						
Cottonseed meal, 2.5 lbs.....	1,011	2.6	760	261	671	1:6.7
Lot II						
Cottonseed meal, 1.25 lbs....	1,004	2.3	792	280	714	1:7.9
With oat straw and silage						
Lot I						
Cottonseed meal, 2.5 lbs.....	908	2.5	676	36	1,062	1:7.0
Lot II						
Cottonseed meal, 4.0 lbs.....	904	2.4	707	33	1,072	1:5.6

With corn silage and clover hay for roughage, 1.25 lbs. of cottonseed meal daily per 1,000 lbs. live weight (the ration having a nutritive ratio of 1:7.9) was not sufficient to balance the ration, as is shown by the larger and more economical gains of the steers fed 2.5 lbs. (this ration having a nutritive ratio of 1:6.7). The second division of the table shows that with corn silage and oat straw for roughage, 2.5 lbs. of cottonseed meal daily per 1,000 lbs. live weight (the nutritive ratio being 1:7.0) produced larger and more economical gains than the allowance of 4 lbs. (the nutritive ratio of the latter ration being 1:5.6). The steers fed the smaller allowance were also equally well finished at the end of the trials.

778. Silage as the sole roughage.—Whether steers fed silage alone for roughage will make as large gains as those supplied some dry roughage in addition, is a question of great importance to the cattle feeder. The following table summarizes the results of 9 trials, in each of which corn silage was fed as the sole roughage with corn and a nitrogenous supplement (cottonseed or linseed meal) to one lot of steers, while another received the same feeds with legume hay in addition. In these trials 2-yr.-old steers averaging 942 lbs. were fed for an average of 156 days.

Silage as the sole roughage vs. silage and legume hay

Average ration	Daily gain Lbs.	Feed consumed for 100 lbs. gain Concentrates Lbs.	Hay Lbs.	Silage Lbs.	Feed cost of 100 lbs. gain Dollars
*Lot I, total of 87 steers**					
Corn silage, 29.2 lbs.					
Corn, 13.5 lbs.					
Supplement, 2.7 lbs.	2.24	693	...	1,283	9.13
*Lot II, total of 87 steers**					
Legume hay, 4.3 lbs.					
Corn silage, 24.3 lbs.					
Corn, 13.8 lbs.					
Supplement, 2.7 lbs.	2.36	701	195	1,065	9.87

*Av. of 5 trials by Skinner, Cochel, and King (Ind. Buls. 136, 153, 163, 167), 1 by Allison (Mo. Bul. 112), 1 by Evvard at the Iowa Station (Breeder's Gaz., 61, 1912, p. 1040), 1 by Rusk at the Ill. Station (Breeder's Gaz., 61, 1912, p. 1041), and 1 by Tomhave and Hickman (Penn. Bul. 133).

Lot II, receiving legume hay in addition to corn silage, made slightly larger gains than Lot I, which was fed no dry roughage. The addition of clover hay to the ration increased the feed cost of 100 lbs. gain by $0.74 on the average but resulted in slightly better finish, the steers in Lot II selling for 7 cents more per 100 lbs. than those in Lot I. In some of the trials the selling price of Lot II was enough higher to offset the more expensive gains, and return a greater profit. In others, feeding silage as the only roughage was the most economical. Where the silage was from corn which had nearly matured and hence was high in dry matter, the addition of dry roughage did not always increase the gains.

As steers fed clover hay in addition to corn silage, ate but little hay, Skinner and King thought that possibly the benefit from the hay lay more in satisfying the appetites of the steers for dry roughage than in the nutrients actually supplied. Accordingly, they conducted 2 trials[86] in which either clover hay or oat straw was fed with corn silage, shelled corn, and 2.5 lbs. of cottonseed meal daily per 1,000 lbs. live weight. In both trials, tho the steers ate an average of but 1.5 lbs. oat straw, this seemed to satisfy their desire for dry roughage, and they made as large gains, at less cost for feed, and sold for fully as high a price as those fed clover hay. It should be pointed out that these results would not have been secured had not sufficient cottonseed meal been fed to balance the oat straw, corn silage, and corn ration.

In a trial at the Nebraska Station[87] Bliss and Lee found that adding 4.0 lbs. of prairie hay per head daily to a ration of corn silage, corn, and cold-pressed cottonseed cake, while not increasing the gains of 2-yr.-old steers, did decrease the feed cost of the gains and result in better finish and greater profit. In a similar trial at the South Dakota Station[88] Wilson secured larger and cheaper gains with yearling steers when prairie hay was added to a ration of corn silage, shelled corn, and linseed meal.

These extensive trials teach that steers will usually make larger gains and reach a higher finish when fed a small amount of dry roughage in addition to silage. An important fact is that this dry roughage may consist of such cheap material as oat straw, rather than the far more expensive legume hay, when a nitrogenous concentrate is fed to balance the ration.

779. Restricting concentrates during first stages of fattening.—It has already been pointed out that it is often profitable to feed only roughages during the first few weeks of the fattening period, with 2 or 3 lbs. of some nitrogenous concentrate, if needed, to balance the ration. **(716)** Especially good results are secured with this system where the chief roughage is silage from well-eared corn. At the Kentucky Station in a 159-day trial Good[89] fed a lot of ten 1062-lb. steers receiving

[86] Ind. Buls. 163, 167.
[87] Nebr. Bul. 151.
[88] S. D. Bul. 137.
[89] Information to the authors.

corn silage and cottonseed hulls for roughage, broken ear corn and cottonseed meal, while a second lot, otherwise fed the same, was fed no corn for the first 2 months, and thereafter shelled corn.

Cheapening gains by limiting concentrates during first of fattening period

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	C' seed hulls Lbs.	Corn silage Lbs.	Feed cost of 100 lbs. gain Lbs.
Lot I, corn thruout trial					
Broken ear corn, 13.6 lbs.					
Cottonseed meal, 3.4 lbs.					
Corn silage, 22.6 lbs.					
Cottonseed hulls, 3.7 lbs.........	2.0	866	188	1,150	13.12
Lot II, no corn for first 2 mo.					
Shelled corn, 7.0 lbs.					
Cottonseed meal, 4.0 lbs.					
Corn silage, 36.3 lbs.					
Cottonseed hulls, 4.3 lbs.........	2.4	472	182	1,541	10.43

In this trial the gains of Lot II, fed no corn during the first 2 months, were not only considerably cheaper, but also somewhat larger than those of Lot I, fed corn from the beginning of the trial. The cause of the larger gains of Lot II, which received less corn, is probably to be found in the fact that, as has already been mentioned, (**736**) shelled corn gives somewhat better results with corn silage than does ear corn.

780. Silage with small concentrate allowance.—To determine the gain made by yearling steers fed corn silage as the sole roughage and only a small allowance of concentrates, Wilson[90] fed 3 lots each of four 648-lb. steers the rations shown in the table for 146 days at the South Dakota Station:

Fattening steers on silage with a small concentrate allowance

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Corn silage Lbs.	Feed cost of 100 lbs. gain. Dollars
I, Linseed meal, 3.0 lbs. Silage, 48.3 lbs.......	2.4	120	1,970	5.86
II, Cottonseed meal, 3.0 lbs. Silage, 41.3 lbs....	2.0	150	2,120	6.64
III, Dried distillers' gr., 3.0 lbs. Silage, 44.0 lbs...	2.2	130	2,030	5.50

*Linseed meal and cottonseed meal, $32.00; dried distillers' grains, $24.00; and corn silage, $4.00 per ton

The silage was of poor quality, for it was cut after having been thrice frosted and when most of the ears were in the milk stage. With only 3 lbs. of concentrates per head daily and this poor silage as the sole roughage, these steers made surprisingly good gains. With feeds at the high prices indicated the gains were exceedingly cheap. This trial shows the possibilities of producing cheap beef thru the use of silage and but a small amount of high-grade concentrates. Tho steers so fattened may not yield "prime" beef, yearlings such as these will furnish meat of a quality which will please all but the most exacting. In this trial the steers fed linseed meal made somewhat the largest gains and at the close of the trial had the appearance of corn-fed

[90]S. D. Bul. 148.

animals. Owing to the low price of dried distillers' grains, the gains on this concentrate were the cheapest.

781. Corn silage vs. shock corn.—Mumford of the Illinois Station[91] divided a bunch of 50 good, thrifty 8-months-old grade Hereford and Shorthorn steer calves, weighing about 500 lbs. each, into 2 lots of 25 each. During 88 days each lot was fed 2 lbs. of oats per head daily, with mixed hay and either corn silage or shock corn from the same field, part having been placed in the silo and the remainder cured in the shock. The calves were not heavily fed, but merely kept in good growing condition, with the results shown in the table:

Corn silage vs. shock corn for wintering steer calves

Average roughage allowance	Daily gain	Corn forage fed		Total gain of	
		Weight	Area	Steers	Pigs
	Lbs.	Tons	Acres	Lbs.	Lbs.
I, Silage, 26.1 lbs. Mixed hay, 4.6 lbs.	1.7	28.8	3.7	3,693	87
II, Shock corn, 13.2 lbs. Mixed hay, 4.0 lbs.	1.4	14.6	5.3	3,133	587

The table shows that the silage-fed calves gained 560 lbs. more than those getting shock corn. Lot I consumed 28.8 tons of corn silage, grown on 3.7 acres. In the same time Lot II consumed 14.6 tons of shock corn, grown on 5.3 acres, or 43 per ct. more area than was required to furnish the corn silage. The silage-fed calves in Lot I gained 3,693 lbs. and the pigs following them only 87 lbs. The steers in Lot II, getting shock corn, gained only 3,133 lbs., but the pigs following them gained 587 lbs. Combining the gains of calves and pigs, the gross returns were practically equal for the 2 lots, but, measured by the area of land required, corn silage was 30 per ct. ahead of shock corn in feeding value.

In a 130-day trial at the Missouri Station[92] Allison found that 2-yr.-old steers fed corn silage with clover hay, shelled corn, and linseed meal made no larger gains than those getting shock corn. However, the silage-fed steers required less concentrates for 100 lbs. gain, made cheaper gains, and sold for 10 cents more per 100 lbs. Including the returns from the pigs following the steers, a ton of dry matter in silage had over 50 per ct. greater feeding value than a ton of dry matter in shock corn. (**302**)

782. Kafir and sorghum silage.—In silage from the sorghums the feeder in the semi-arid sections has an admirable substitute for corn silage. (**309**) During each of 3 years Cochel wintered steer calves at the Kansas Station[93] on silage from corn, kafir, or sweet sorghum, with the results shown in the table. In addition to the silage, during the first and third years 1 lb. of cottonseed meal was fed per head daily and during the second year 1 lb. of corn and 1 lb. of linseed meal. Forty-two calves were fed each kind of silage for periods averaging 107 days.

[91] Ill. Bul. 73. [92] Mo. Bul. 112.
[93] Kan. Bul. 198; Kansas Industrialist, Apr. 18, 1914, May 1, 1915.

Kafir and sorghum silage compared with corn silage

Silage eaten per head daily	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Silage Lbs.
Lot I, Corn silage, 26.8 lbs.	1.15	113	2,330
Lot II, Kafir silage, 26.3 lbs.	1.25	104	2,104
Lot III, Sweet sorghum silage, 26.6 lbs.	1.08	127	2,467

In these trials the different kinds of silage had about the same value, kafir being slightly superior to corn, and sweet sorghum ranking lowest. Cochel advises growing for silage whichever crop will yield the greatest tonnage.

783. Comparison of silages for the South.—Lloyd of the Mississippi Station[94] conducted a 137-day trial with 4 lots, each of 4 to 5 steers averaging 1,145 lbs., to compare the values of silage from corn, sweet sorghum, cowpeas and Johnson grass, and corn stover. The steers in each lot were fed 6.5 lbs. cottonseed meal per head daily, with silage as shown in the table:

Silage from sorghum, cowpeas and Johnson grass, and corn stover

Silage per head daily	Daily gain Lbs.	Feed for 100 lbs. gain Meal Lbs.	Silage Lbs.
Lot I, Corn silage, 46.1 lbs.	1.8	365	2,588
Lot II, Sweet sorghum silage, 46.1 lbs.	1.6	411	2,911
Lot III, Cowpea and Johnson-grass silage, 46.1 lbs.	1.3	495	3,510
Lot IV, Corn-stover silage, 46.1 lbs.	0.7	997	7,070

Corn silage gave the best results, followed closely by sweet sorghum silage. Corn stover silage produced the lowest gains, due to the fact that it contained no grain and also because much was refused by the steers.

784. Roots.—Wherever corn or the sorghums thrive, silage from these crops provides cheaper succulence than do roots. In northern districts where root crops flourish but where corn will not mature sufficiently for silage, roots are a valuable feed for beef cattle. At the South Dakota Station[95] in a 90-day trial Wilson fed lots of 4 yearling steers, each averaging 800 lbs., 19.4 lbs. of shelled corn and 1.7 lbs. linseed meal per head daily with hay and silage from corn in the dent stage or roots, as indicated in the table, to compare the value of these succulent feeds:

Roots vs. corn silage for fattening steers

Allowance per head daily	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Prairie hay Lbs.	Silage or roots Lbs.
Lot I, Corn silage, 7.0 lbs. Prairie hay, 5.8 lbs.	2.54	835	227	277
Lot II, Sugar beets, 6.3 lbs. Prairie hay, 5.5 lbs.	2.55	823	217	248
Lot III, Mangels, 9.0 lbs. Prairie hay, 7.4 lbs.	2.61	813	284	343
Lot IV, Stock beets, 8.9 lbs. Prairie hay, 6.1 lbs.	2.39	873	257	374

[94] Information to the authors.
[95] S. D. Bul. 137.

In this trial when fed in a limited allowance of 6 to 9 lbs. per head daily, roots were fully equal, pound for pound, to good corn silage. Mangels were more palatable than the other roots and produced the largest gains. In 2 trials at the Ontario Agricultural College[96] in which a larger allowance of silage or roots was fed than in the foregoing trial, Day found that silage had a somewhat higher value, pound for pound, than roots, due to the larger percentage of dry matter it contains. **(365-73)**

785. Sweet potatoes; cassava; Japanese cane.—At the Florida Station[97] Stockbridge fed 3 lots of 4 steers each averaging 446 lbs. the following rations for 70 days to test the value of sweet potatoes and cassava in beef production.

Cassava and sweet potatoes for fattening steers

Average ration per 1,000 lbs. live weight	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Roughage Lbs.
Lot I			
Sweet potatoes, 35 lbs. Pea-vine hay, 10 lbs. Cottonseed meal, 4 lbs. .	1.8	226	2,541
Lot II			
Cassava, 35 lbs. Pea-vine hay, 10 lbs. Cottonseed meal, 4 lbs...	2.1	195	2,188
Lot III			
Crab-grass hay, 20 lbs. Cottonseed meal, 5 lbs. Corn meal, 5 lbs.	1.9	517	1,033

It is shown that cassava and sweet potatoes are satisfactory in beef production when combined with pea-vine hay and cottonseed meal. The steers fed crab-grass hay required more than twice as much concentrates for 100 lbs. of gain as those in the other lots. Scott of the same Station[98] reports that steers fed on corn, velvet beans, and sweet potatoes barely maintained their weight, due to the fact that sweet potatoes are too laxative when fed without some roughage. When Japanese cane was added to the ration the results were satisfactory.

In another trial by Scott[99] 930-lb. steers fed an average ration of 21.3 lbs. Japanese cane, 7.3 lbs. corn, and 4.2 lbs. cottonseed meal gained 1.6 lbs. per head daily for 90 days, requiring 698 lbs. of concentrates and 1,298 lbs. of Japanese cane for 100 lbs. gain.

786. British system of fattening cattle.—The great value of succulence in reducing the amount of high-priced concentrates needed to fatten cattle is well shown in the extensive compilation by Ingle[100] of all the cattle-feeding trials carried on in Great Britain between the years 1835 and 1908—201 in number. From this report the following examples are chosen as broadly illustrating the British system of fattening beef cattle.

[96] Ont. Agr. Col. Rpts. 1901, 1902.
[97] Fla. Rpt. 1901. [98] Fla. Rpt. 1909. [99] Fla. Rpt. 1912.
[100] Trans. Highl. and Agr. Soc. of Scotland, 1909.

Rations used by British farmers in beef production

Average ration	No. fed	Initial weight Lbs.	Daily gain Lbs.	Total gain per head Lbs.
Shorthorns, 2 to 5 years old, fed 98 days				
Swedes, 171 lbs. Linseed cake, 2.4 lbs.				
Straw, 14 lbs. Corn meal, 2.0 lbs.........	4	1,305.0	3.0	292
Irish yearlings, fed 112 days				
Turnips, 50 lbs. Cottonseed cake, 3.6 lbs.				
Oat straw, 8.4 lbs. Dried brewers' grains, 5.8 lbs.	10	942.2	1.3	149
Irish 2-yr.-olds, fed 133 days				
Roots, 112.0 lbs.				
Hay and straw, 8.0 lbs. Linseed cake, 8.7 lbs.	4	1,030.4	2.1	280
Aberdeen-Angus, fed 112 days				
Mangels, 108.8 lbs.				
Oat straw, 8.0 lbs. Cottonseed cake, 3.0 lbs..	6	947.6	1.9	211
Galloways, 2 to 3 years old, fed 100 days				
Swedes, 150.0 lbs.				
Oat straw, 7.0 lbs. No concentrates.........	3	933.0	1.4	143
Irish 3-yr.-olds, fed 88 days				
Pasture Cottonseed cake, 2.8 lbs.				
Corn meal, 2.8 lbs.................	10	876.2	3.7	322
Shorthorn 3-yr.-olds, fed 123 days				
Swedes, 40.5 lbs. Cottonseed cake, 5.0 lbs.				
Hay, 16.2 lbs. Linseed cake, 3.0 lbs.				
Barley, 1.0 lb............	8	1,178.4	2.4	294

The American cattle feeder who critically reviews the data given will be impressed first of all with the surprisingly small amount of concentrates employed in the ration. In the 201 trials presented by Ingle the largest amount of concentrates fed per head daily to any lot was 13 lbs. In a few cases no concentrates were fed, but usually the allowance for each bullock was 6 or 7 lbs. per day. The rich nitrogenous concentrates such as linseed meal, cottonseed meal, dried brewers' and distillers' grains, and peanut cake are the ones commonly employed, followed by barley and corn meal more sparingly used. Equally striking is the heavy use of roots, the amount fed ranging from 35 lbs. per head daily to above 150 lbs. in extreme cases. The light feeding of concentrates and the heavy feeding of roots is accompanied by the large consumption of hay and straw, which the British feeder chaffs or cuts, and mixes with the pulped or sliced roots and meal before feeding. It will be further observed that the British farmer generally feeds quite mature bullocks, and that the feeding period is relatively short, ranging from 80 to 120 days. It is probable that the cattle are usually in good flesh when the feeding begins.

In studying these figures we should remember that it was the British farmer who originated and developed all the valuable breeds of beef cattle now scattered over the globe, and his ability and success in producing beef of high quality is unquestioned. With the high prices now prevailing for concentrates in this country and the ever upward tendency, our feeders may wisely adopt a similar system of beef production, employing silage from corn and the sorghums instead of the roots which are the basis of English feeding.

CHAPTER XXVIII

RAISING BEEF CATTLE

I. The Breeding Herd

In establishing a herd from which to breed animals for beef production the first step should be to select well-bred individuals of the beef breeds, having the conformation which betokens off-spring that will make economical gains, mature early, and yield carcasses with a large percentage of high-priced cuts of meat. **(717-25)** Where cows are kept only for raising calves for beef, the cost of their keep for an entire year must be charged against the fatted steer. In reducing the cost of beef production it is therefore essential that the breeding herd be maintained as cheaply as possible, yet kept in vigorous breeding condition.

787. Breeding cows.—Cows kept solely for beef production are commonly grazed on pasture during the growing season, the suckling calves running with their dams. Usually the pastures thus utilized will be the land least suited to tillage. Where land is high-priced and there is but little waste land for grazing, the herd may often be maintained most cheaply on limited pasturage supplemented by summer silage. **(412)** Pure water, salt, and shade should always be supplied the herd at pasture.

In winter the herd may be maintained entirely on roughage where legume hay is available, or on carbonaceous roughages with enough of some such nitrogenous concentrate as cottonseed or linseed meal to balance the ration. They should not be allowed to run down in flesh, else they will be unable to produce vigorous calves and nourish them with a goodly flow of milk. **(91, 120)**

The winter feed and care may range from the most intensive system, where the herd is fed in barn or shed with the freedom of exercise paddocks, to the practice yet followed in some of the grazing districts of the West, where the only feed is that furnished by the winter range on which the grass has been allowed to grow up and mature. However, bitter experience has taught the western stockman that he must provide against winter's rigors by having available a supply of feed to supplement the range. On many farms the herd may glean much of their living from aftermath and stalk or stubble fields, thereby materially reducing expenses.

788. Wintering beef cows.—Mumford of the Illinois Station[1] divided a lot of 860-lb. grade Angus cows which had suckled their calves the previous summer and were thin in flesh into bunches of 10 each and

[1]Ill. Bul. 111.

fed them the rations shown below during 140 days in winter. Twenty-eight per ct. of the corn silage and 54 per ct. of the shock corn consisted of ears.

Wintering breeding cows on silage and shock corn

Average ration	Daily gain Lbs.	Av. gain per head Lbs.
Lot I		
Corn silage, 16.7 lbs.		
Oat straw, 9.6 lbs. Clover hay, 3.5 lbs.	1.1	150
Lot II		
Shock corn, 8.7 lbs.		
Oat straw, 10.8 lbs. Clover hay, 3.5 lbs.	0.8	106
Lot III		
Corn stover (42 days), 21.7 lbs.		
Shredded stover (98 days), 10.3 lbs.		
Oat straw, 8.2 lbs. Clover hay, 1.6 lbs.	0.4	58

At the close of the trial the cows in Lot III, fed only 1.6 lbs. of clover hay, were in poor condition, having made but small gain. The cows of Lots I and II, which had made good gains, appeared about the same until after calving, when those in Lot I, which had been fed silage, were in decidedly superior form. It required the feed grown on one-third of an acre to support a cow making fair gains for 140 days with Lots I and II, and that from one-fifth of an acre to little more than maintain a cow of Lot III.

789. Wintering beef cows on silage and cottonseed meal.—During 3 winters Cochel, Tomhave, and Severson maintained one lot of 10 pure-bred Shorthorn cows and another of Aberdeen-Angus cows at the Pennsylvania Station[2] on silage as the sole roughage with 1 lb. of cottonseed meal per head daily. Both lots were kept in an open shed or a barn open on one side, with access to an adjacent lot. The results of the trials, which averaged 155 days, are shown in the following table:

Wintering beef cows on silage and cottonseed meal

Average ration	Initial weight Lbs.	Gain per head Lbs.	Feed cost per head Dollars	Total cost per head Dollars	Value of manure Dollars	Net cost per head Dollars
Lot I, Shorthorns						
Corn silage, 58.8 lbs.						
Cottonseed meal, 1.0 lb.	1,180	51	18.28	26.47	7.33	19.14
Lot II, Angus						
Corn silage, 57.8 lbs.						
Cottonseed meal, 1.0 lb.	1,143	47	18.05	26.24	7.33	18.91

The cows in both lots were maintained in satisfactory condition on all the silage they would eat, with only 1 lb. of cottonseed meal per head daily, even tho several were suckling calves during the winter. With corn silage at $3.50 and cottonseed meal at $30.00 per ton, the feed-cost of wintering the cows was $18.28 and $18.05. Including the straw used for bedding (1,088 lbs. per cow at $8 per ton), $2.34 per cow for labor, and $1.50 per cow for interest on shed and silo, the total gross cost per

[2]Penn. Bul. 118; Rpt. 1913; and information to the authors.

cow was $26.47 and $26.24, respectively, for the 2 lots. Deducting the value of the manure at $1.50 per ton, the net cost of wintering the cows was about $19 per head.

During the remainder of the year the cows, with the calves at their sides, grazed a pasture so rough that it washed badly when in tilled crops. Allowing 2 acres of pasture per cow, the average yearly cost of maintaining the cows, including labor, was as follows: Cost of wintering, $19.02; cost of pasturing, $7.36; interest on value of cow, $5.40; service of sire, $2.00; total $33.78. With 80 per ct. of the cows raising calves each year, a calf at weaning time would cost $42.22.

790. Plains rations for wintering cows.—In a 100-day trial at the Hays, Kansas, Branch Station,[3] Cochel wintered 4 lots, each of nineteen 905-lb. cows, on the roughages shown in the table with 1 lb. of cottonseed meal per head daily in addition:

Rations for wintering cows in the plains district

Average roughage allowance		Daily gain Lbs.	Feed cost per head* Dollars
I, Kafir silage, 35.6 lbs.	Wheat straw, 14.2 lbs.	1.34	6.30
II, Kafir silage, 20.0 lbs.	Wheat straw, 17.2 lbs.	0.56	4.44
III, Kafir fodder, 27.2 lbs.	Wheat straw, 10.3 lbs.........	0.50	9.91
IV, Kafir stover, 25.6 lbs.	Wheat straw, 10.8 lbs.	0.35	5.61

* Kafir silage $2.66, kafir fodder $5.00, kafir stover $3.00, wheat straw $0.50, and cottonseed meal $30.00 per ton.

Lot I, fed 35.6 lbs. kafir silage, 14.2 lbs. wheat straw, and 1.0 lb. cottonseed meal per head daily, made the largest gains, but at a greater cost than Lot II, where the silage allowance was only 20.0 lbs. Kafir silage not only carried the cows thru the winter in better condition than kafir fodder, but was also easier to feed. The advantage of ensiling the sorghum crop is shown by the fact that Lot II, fed kafir silage, consumed the crop from only half as large an area of kafir as Lot III, fed kafir fodder, and yet made as large gains. That fair results may be secured when only low-grade roughages are used with 1 lb. of cottonseed meal per head daily is shown by Lot IV. In another trial Cochel[4] found that when cows were wintered on a ration of 12.1 lbs. kafir stover, 14.1 lbs. wheat straw, 5.4 lbs. kafir silage, and 1 lb. of cottonseed cake, the cost of feed per cow for 136 days was $5.70 and of labor, $1.94, making a total of $7.64, from which should be deducted the value of the manure produced.

791. The beef bull.—On the range the bulls run with the cows, but under farm conditions it is best to confine the bull during the summer, preferably in a well-fenced pasture lot. It will then be possible to keep a record of the date when the cows are due to calve, and the bull so handled can serve a larger number of cows a year. The same general principles apply to the feed and care of the beef bull as with the dairy bull, which have already been discussed. **(708)** As Mumford writes,[5]

[3] Kan. Bul. 198. [4] Information to the authors. [5] Beef Production, p. 165.

"He should be kept in good, thrifty condition, and if it is found that he requires an abnormal amount of feed to maintain this condition, in other words, that the bull is a 'hard keeper', he is not well calculated to sire cattle possessing good feeding qualities, and should be replaced."

II. Raising Calves for Beef; Veal Production

792. The beef calf.—Under the simplest method of beef production, as on the range, the calves are dropped in the spring and run with their dams during the summer. Under farm conditions some prefer to allow the calves to suck only at stated intervals, 3 times a day at first, and later twice.

Where the calf remains with the dam her udder should, for a time, be stripped night and morning lest neglect bring garget and destroy her usefulness. If the calf is getting too much milk, as shown by scouring, cut off part, remembering that the last drawn portion is the richest in fat, and that richness as well as quantity causes digestive troubles. **(117)** The greatest danger under this system comes at weaning time, when, if the calf has not been taught to eat solid food, it pines and loses weight. To avoid this, before weaning it should be taught to eat shelled corn, whole oats, wheat bran, linseed meal, hay, etc. The first departure from this simple and primitive method is putting two calves with each cow, which is feasible where the cow yields a good flow of milk.

Suckling calves should gain 2 lbs., or over, per head daily if their dams give a good flow of milk. At the Pennsylvania Station[6] Hunt fed 3 calves whole milk containing 4.6 per ct. of fat for 161 days. They gained 1.77 lbs. each daily, requiring 8.8 lbs. of whole milk, and 1 lb. of hay and 1 lb. of grain for each pound of growth. Martiny[7] found that from 3.5 to 6 lbs. of new milk was sufficient to produce a pound of gain, live weight, with calves between the first and fifth weeks, while older ones required from 16 to 20 lbs. Linfield of the Utah Station[8] found that up to 14 weeks of age the calf takes less dry matter than the pig for 1 lb. of gain, and after that more, possibly because of the greater amount of roughage then used in the ration. Beach of the Connecticut (Storrs) Station[9] found that calves required 1.03 lbs., lambs 1.08 lbs., and pigs 1.36 lbs. of dry matter in whole milk for each pound of gain made. **(117)**

While in some districts it is still best to rear the beef calf on whole milk from dam or pail, over large sections of the country it is now more profitable to sell the fat of the milk in butter or cream and rear the calf on skim milk with proper supplements. This method involves increased labor, skill, and watchfulness on the part of the feeder, but its success has been widely demonstrated. The method to be employed is

[6] Penn. Rpt. 1891.
[7] Die Milch, 2, 1871, pp. 9-15.
[8] Utah Bul. 57.
[9] Conn. (Storrs) Rpt. 1904, p. 118.

not different from that already detailed for the rearing of the dairy calf, **(678-94)** except that the beef calf should be forced to more rapid gains thru more liberal feeding.

Calves that fail to thrive when sucking the cow or when fed on rich milk should have their allowance reduced or should be given part skim milk. Lime water or wood ashes may possibly prove correctives in cases of trouble from this source. **(117)** The lime water used in such cases is made by dropping a lump of unslaked lime into a jug filled with water and keeping the jug corked. A tablespoonful or more of lime water should be given with each feed.

After weaning, growth should be continuous. If the calves are not at pasture, they should be fed plenty of good roughage, with sufficient concentrates to produce the desired gains. As has been shown in the discussion of raising dairy heifers **(704)**, for young beef cattle nothing excels good legume hay, rich in protein and bone-building mineral matter. Where this is not available nitrogenous concentrates should balance the ration.

The majority of beef producers prefer to have calves dropped in the spring, as the cows may then be wintered more cheaply, with less shelter, and less care. Mumford[10] points out that fall calves not fattened as baby beef must be carried thru 2 winters, while spring calves may be sold at the age of 18 to 20 months, after but 1 winter. Some, however, prefer fall calving, reasoning that the cow is in better condition to deliver her calf after the summer on pasture and the fall calf is better able to handle grass, and endure the heat and flies the following season.

793. Veal production.—For the highest grade of veal whole milk is the sole feed allowed, and growth must be pushed as rapidly as possible, the whole process being completed before there is any tendency in the flesh to take on the coarser character of beef. Such veal commands a high price in some of the European markets, and the butchers are extremely expert in judging whether the calf has received any other feed than whole milk. Only when whole milk has been used exclusively, is the white of the eye of the veal calf free from any yellow tint, and the inside of the eyelids, lips, and nose perfectly white. In this country veal of this kind can be profitably produced only for a special market. A less expensive method of producing veal is to feed a limited amount of whole milk supplemented by grain, or skim milk may be gradually substituted, as with dairy calves. **(687-8)** With the latter method, considerable skill is necessary to feed the calves so they will gain rapidly without going off feed.

794. Dutch veal.—In Holland, where unusually heavy, well-fatted calves are a specialty, the following practices are common, according to Forssell:[11] The new-born calf is placed in a stall 6.5 ft. long by 1.6 ft. broad and about 5 ft. high, the stall being so narrow that it cannot turn around, tho it can lie and stand comfortably. The floor of the stall is

[10] Beef Production, p. 166. [11] Fodret och Utfodringen, 1893, p. 155.

of slats or perforated boards, and is littered daily so that the animal has a perfectly dry berth. The calf barn is kept dark. Two or 3 times daily the calves get as much milk as they will drink, and during the first 14 days only the dam's milk is fed. Eggs or other by-feeds are not given. The calf consumes on the average about 34 lbs. of whole milk daily for the whole fattening period of 10 to 12 weeks, at the end of which time the veal is considered to be at its best. To prevent the calves from eating feed other than milk, they are muzzled if straw or other roughage is used for bedding. Finely-ground shells and sand are given to prevent scouring. The dressed weight ranges from 187 to 220 lbs., or, according to Rost,[12] from 220 to 330 lbs. One lb. of gain is made in the beginning from 8 lbs. of milk and toward the close from 12 lbs., the average being 10 lbs.[13] The fat calf dresses from 55 to 60 per ct. of its live weight.

795. Scotch veal.—At Strathaven, Scotland, a region noted for the excellence of its veal,[14] the youngest calves receive the first drawn milk and the older ones the last and richer portion. Thus one calf is often fed portions of milk from 2 or 3 cows. After the third week they receive as much milk twice a day as they will take. Following feeding they are bedded, the stable being kept rather warm and dark. Lumps of chalk are placed where the calves have access to them. The fattening period continues from 5 to 7 weeks, when a dressed weight of 100 to 120 lbs. is secured.

In the vicinity of London veal calves fed for about 10 weeks in isolated pens, as in Holland, ordinarily dress 140 lbs.

III. Growing Beef Cattle

796. Summer care.—Except where calves are being fattened for baby beef (**820**), growing beef cattle are not ordinarily given any feed in addition to good pasture. When necessary to keep the animals growing, additional feed should be supplied, such as summer silage, soiling crops, or specially grown pasture crops. Considerable fall pasturage is furnished by aftermath on meadows or by the stubble fields, especially where a small amount of rape seed is sown with the spring grain.

797. Wintering growing cattle.—The ration needed to carry growing cattle thru the winter in good condition will depend on their age, and on whether it is desired to have them make substantial gains or merely come thru the winter in thrifty condition to make maximum gains on pasture the following summer. While yearlings and 2-yr.-olds may be wintered on roughage only, for calves 1 to 3 lbs. of concentrates per head daily will be needed in addition, for it is important to keep the calf growing steadily, enlarging its framework but not laying on fat. Where cattle are to be grazed the third summer without fattening, the effort should be to grow as large a framework as possible the second winter,

[12] Molk. Zeit., 1894, p. 547.
[13] Kraft, Landwirtschaft, 3, p. 163.
[14] Molk. Zeit., 1894, p. 547.

leaving the animal thin but thrifty. Mumford writes:[15] "The more cattle gain on concentrated feeds in winter the less they will gain on grass in summer. That is to say, if corn is fed liberally during the winter months the cattle will not make as large gains when turned to grass as they would were they wintered on roughage, and not the best roughage at that."

Where cattle are to be fattened on pasture the summer following the second winter, a reasonable storage of fat toward the close of winter and in early spring will helpfully shorten the summer feeding period. In such cases excellent feeds for the last of winter and early spring are legume hay and silage rich in ear corn. These, with a moderate grain allowance, will warm the animals up, start fattening, and send them to grass in prime condition to make the most of the heavy feeding of grain which follows. Calves are not able to utilize such coarse roughages as older cattle will consume.

At the North Platte, Nebraska, Station[16] Snyder conducted 2 trials in which lots of 18 and 20 steer calves, respectively, were wintered on the roughages shown in the table with 2 lbs. per head daily in addition of a mixture of 2 parts corn and 1 part oats. The following and the second summers all lots ran on a canyon pasture. The second winter the steers were fed roughage alone.

Average daily gains of steers fed various roughages during winter

Hay or fodder fed during winter	First year		Second year	
	Winter Lbs.	Summer Lbs.	Winter Lbs.	Summer Lbs.
Alfalfa	1.08	1.07	0.72	0.57
Alfalfa and prairie	0.99	0.93	0.70	0.55
Alfalfa and sorghum	1.05	0.94	0.87	0.49
Prairie	0.46	1.22	0.20	1.21
Sorghum	0.41	1.19	0.42	0.92

In all instances the steers fed prairie hay or sorghum fodder made much smaller winter gains than those fed alfalfa hay. When half alfalfa hay and half prairie hay or sorghum fodder was fed, the gains were about as large as when only alfalfa was fed. The steers that made the best winter gains made smaller gains the following summer, but the total gains for the entire year were larger for the lots fed some alfalfa.

Trials by Cochel at the Kansas Station show that calves may be wintered satisfactorily on silage from corn, kafir, or sweet sorghum, with 1 lb. of cottonseed or linseed meal per head daily in addition. (782) The manner in which cheap roughages may be largely utilized even in wintering calves, when combined with silage, is shown in a 144-day trial by Cochel[17] in which 30 calves fed a ration of 3.3 lbs. wheat straw, 2.3 lbs. corn stover, 2.9 lbs. foxtail and damaged alfalfa hay, 6.8 lbs. kafir silage, and 0.8 lb. of a concentrate mixture, gained 41.8 lbs. each at a daily feed cost of 3.3 cents per head. The total gross cost of wintering

[15] Beef Production, p. 46.

[16] Nebr. Buls. 105, 117.

[17] Information to the authors.

the calves was only $5.72 per head, from which should be deducted the value of the manure.

798. Wintering yearlings without grain.—At the Missouri Station[18] during each of 4 winters Waters fed lots of 4 or 5 high-grade yearling Hereford and Shorthorn steers each for periods of 49 to 92 days. These steers, rather thin in flesh and averaging about 725 lbs. in weight, were fed the following roughages of medium quality, without grain, with the results shown below:

Roughages for wintering yearling steers without grain

Average roughage allowance	Roughage refused Per ct.	Av. daily gain or loss Lbs.
Lot I, Timothy hay, 17.6 lbs.*	16.3	+0.31
Lot II, Whole corn stover, 31.3 lbs.*	40.8	−0.18
Lot III, Shredded corn stover, 23.6 lbs.†	35.8	−0.14
Lot IV, Ensiled corn stover, 47.4 lbs.†	4.6	+0.58
Lot V, Corn stover, 13.6 lbs., clover hay, 13.6 lbs.†	27.0	+0.44

* Four trials. † Two trials.

It is shown that yearling steers in thin condition made only a small gain when wintered on timothy hay alone. Those fed whole or shredded field-cured corn stover lost in weight, while on ensiled stover, or stover and clover hay there were substantial gains.

Skinner and Cochel[19] in a survey of Indiana cattle feeding found that only about one-fourth of the feeders from whom replies were received fed grain in any form to stockers being carried thru the winter, and of these the majority fed grain late in the spring just previous to turning on grass.

799. Wintering yearlings with a limited grain allowance.—During 4 winters Waters[20] compared various roughages when fed without limit to yearling steers with a limited allowance of shelled corn. Lots of 4 steers each, similar to those fed in the preceding trials and averaging about 750 lbs. in weight, were fed the rations given in the following table for periods of 66 to 120 days:

Roughages for wintering steers getting a limited grain allowance

Average roughage allowance	Corn fed per day Lbs.	Daily gain or loss Lbs.	Feed for 100 lbs. gain Corn Lbs.	Feed for 100 lbs. gain Roughage Lbs.
Whole corn stover, 29.3 lbs.*	3.8	−0.32	...	....
Corn stover, 11.0 lbs., clover hay, 10.9 lbs.‡	5.3	1.37	400	1,754
Clover hay, 19.0 lbs.†	6.0	1.97	305	966
Timothy hay, 16.6 lbs.‡	5.3	1.01	552	1,815
Cowpea hay, 19.0 lbs.†	5.5	1.42	362	1,343
Alfalfa hay, 17.3 lbs.*	6.0	1.63	368	1,061
Millet hay, 13.1 lbs.*	6.0	0.37	1,613	3,516
Sorghum hay, 25.8 lbs.†	6.0	0.91	809	2,921

* One trial. † Two trials. ‡ Three trials.

The steers fed whole corn stover with an allowance of 3.8 lbs. of shelled corn per day lost 0.32 lb. each daily. Those fed equal parts of

[18] Mo. Bul. 75. [19] Ind. Cir. 12. [20] Mo. Bul. 75.

stover and clover hay gained 1.37 lbs. each daily, requiring only 400 lbs. of corn and 1,754 lbs. of roughage for 100 lbs. of gain. Waters points out that stover serves best when combined with a limited quantity of clover or other leguminous hay, a point of great importance. The steers fed clover hay made nearly twice as large and far more economical gains than those fed timothy hay, another fact of great value to the feeder. Alfalfa hay proved about equal to clover hay, and cowpea hay of slightly lower value. Millet and sorghum hay made a poor showing when fed with shelled corn.

Waters concludes: "One ton of timothy hay is worth as much as 3 tons of whole corn stover when each is the sole feed. **(622)** Shredding corn stover did not enhance its feeding value, and nearly as great waste occurred as with whole corn stover." While the steers fed whole, or shredded field-cured corn stover did not maintain their weight, those fed silage made from corn cut at the same time and from which all the ears had been removed made small daily gains. More dry matter was given in the stover, but a large part was left uneaten, while nearly all the silage was consumed.

At the Tennessee Station[21] Willson fed 3 lots each of 5 steers and a fourth of 13 steers the rations shown in the following table for 133 days during the winter:

Silage, straw, or cottonseed hulls for wintering stockers

Average winter ration	Average gain per head Winter Lbs.	Summer Lbs.	Total Lbs.	Feed cost of wintering Dollars
I, Silage, 30.2 lbs.	–48	292	244	6.03
II, Straw, 13.6 lbs. Cottonseed meal, 1 lb.	21	251	273	7.06
III, Straw, 14.4 lbs. Cottonseed meal, 2 lbs.	62	237	299	9.07
IV, C'seed hulls, 13.7 lbs. C'seed meal, 3 lbs.	–11	302	291	9.14

The steers fed corn silage alone failed to maintain their weight, while those fed straw (half oat and half wheat) with 1 to 2 lbs. of cottonseed meal per head daily made small gains in weight. In this trial straw was superior to cottonseed hulls.

In another trial steers wintered on silage alone gained only 16.4 lbs. each, while others fed 1 lb. cottonseed meal per head daily in addition gained 109.6 lbs. Steers fed corn stover and 1 lb. of cottonseed meal gained 62.6 lbs. each. Willson concludes that corn stover or straw, with 1 to 2 lbs. of cottonseed meal per head daily, makes a satisfactory ration for wintering stocker steers that are to be grazed during the following summer and finished for the block the next winter. The larger the winter gain, the smaller was the summer gain generally, tho where the steers made no gains during the winter or lost in weight they made smaller total gains during the year than those which had gained 80 to 100 lbs. during the winter.

[21] Information to the authors.

CHAPTER XXIX

COUNSEL IN THE FEED LOT

In an earlier chapter we have learned that the main object of fattening is not the accumulation of fatty tissue in the body, but an improvement in the quality of the lean meat thru the deposition of fat in the lean-meat tissues. **(121)** When fattening has progressed to this point the meat shows the characteristic "marbling" and is of better flavor and much more tender and juicy than that from the unfattened animal.

Fat is concentrated fuel energy stored as surplus in the animal's body against the time of need. Impelled by a hearty appetite, under liberal feeding the steer at first lays on fat rapidly, storing it everywhere within the body—among the fibers of the muscles, within the bones, the body cavity, etc. After a few weeks on liberal feed the appetite loses its edge, and the steer shows indifference and a daintiness in taking his food not at first noticed; every pound of increase now means the consumption of more food than formerly. The fattening process may be likened to inflating a collapsed football—the operation, easy and rapid at first, grows more and more difficult until the limit is reached. **(714)**

The principal indications of a well-fattened animal which the experienced judge of beef cattle looks for are a fullness at the root of the tongue and the base of the tail, a well-filled flank, and a full "twist" and "cod," in addition to a smooth, firm covering of fat over the body.

The increase of the growing animal is largely water, with some protein, some fat, and a little mineral matter; the increase of the fattening animal on the other hand, is largely fat, with a little water, and a trace of protein and ash. It takes far more food for a given increase with the fattening than with the growing animal. The laying on of fat calls for heavy feeding with rich feed and is always an expensive process.

800. The ration for fattening.—In the general discussion of the requirements for fattening, given in Chapter V, we have seen that the nutrient requirements of the fattening animal differ materially from the requirements for growth. With the mature animal there is comparatively little storage of protein or of mineral matter, as the muscular tissues and the skeleton are already grown. The ration may therefore have a relatively wide nutritive ratio, but even with a mature animal, when the nutritive ratio is wider than 1:8 or 1:10 the digestibility of the ration will be depressed and a waste of feed result. **(84)**

In this country most of the beef cattle are now fattened before they are full-grown, and the tendency is increasing to shorten still further the period before the steer reaches the block. For the fattening of such animals sufficient protein must be furnished to provide for the growth in protein tissues which takes place during the fattening period. In the preceding chapter it has been pointed out that larger and more economical gains were made by 2-yr.-old steers on a ration having a nutritive ratio of 1 :7.0 than when the ratio was 1:9.0. **(776)** It has further been shown that when the nutritive ratio was 1:5.6 no larger gains were secured than when it was 1:7.0. **(777)**

Studies made by the authors, of southern feeding trials in which the only concentrate used was cottonseed meal, show that exceedingly satisfactory gains are produced on rations having a nutritive ratio as narrow as 1:3.8 or even narrower. From these data, and studies of other trials by the authors, it appears that the nutritive ratio of the ration for the 2-yr.-old fattening steer may range from 1:3.8 to nearly 1:8.0 without influencing the results. When the nutritive ratio is 1:8.0, slightly smaller gains will usually result than on a narrower ration, but under some conditions a ration having this ratio may be the more economical.

It is evident from this discussion that the allowance of crude protein prescribed in the Wolff-Lehmann standard is unnecessarily high, the nutritive ratio there advised ranging from 1:5.4 to 1:6.5. On the other hand, at least for the 2-yr.-old steer, which is yet growing, the Kellner and Armsby standards prescribe insufficient protein for maximum gains. **(170, 174)** These facts have been taken into consideration in the recommendations set forth in the Modified Wolff-Lehmann standards, which have already been discussed. (**187-9; Appendix Table V**)

The proportion of concentrates needed in the ration will depend on the condition of the cattle when placed on feed, on the rapidity with which it is desired to fatten them, and on the degree of finish which the demands of the market make most profitable. As has been shown, feeders in thin flesh require a long feeding period, during the first part of which the ration may consist largely of palatable roughage. On the other hand, fleshy feeders may be finished in a comparatively short time on a more concentrated ration. **(716, 779, 780)** Hastening the fattening naturally means supplying a heavier allowance of concentrates than when the period is lengthened. Where the market does not pay a premium for the prime beef furnished by the highly finished animal, a heavy concentrate allowance is not profitable. (**768**)

801. Practical rations for fattening cattle.—The reader who wishes to know the quantity and proportion of the various concentrates and roughages in well balanced rations for fattening cattle will find his wants adequately met in the two preceding chapters, wherein are summarized the principal feeding trials at the different experiment stations, covering almost every form of concentrates and roughages. Out of the many presented he should be able to find several that approximate his individual conditions.

802. Getting cattle on feed.—Mumford[1] recommends that cattle going on full feed be given all the clover or alfalfa hay they will eat without

[1]Beef Production, pp. 49-52.

waste. In addition, start with 2 lbs. of corn per steer per day, increasing 1 lb. daily until 10 lbs. is fed. From this time the allowance may be gradually increased 1 lb. every third day until they are on full feed. Cattle getting from 12 to 15 lbs. of corn daily should have about 12 lbs. of clover or alfalfa hay per 1,000 lbs. live weight; later only about one-fourth of the ration should be roughage. Where the feeding period is to cover 6 months, from 30 days to 6 weeks should elapse before the cattle are on full feed. In such cases proportionally more good roughage, such as clover or alfalfa, is fed. While the animals so managed do not make such rapid gains at first, near the close of the feeding period the gains are as large as ever and more economical and satisfactory. As shown before (**729**), Mumford reports success in using the self-feeder in getting steers on full feed, the grain being mixed with chaffed hay.

803. Hogs following steers.—The following is condensed from Waters:[2] The number of hogs required to utilize the waste per steer will vary greatly with the character of the feed, the way in which it is prepared, and with the size and age of the cattle being fed. The range is from 2 to 3 hogs per steer on snapped corn, 1.5 per steer on husked ear corn, about 1 per steer on shelled corn, and 1 hog to 2 or 3 steers on crushed or ground corn.

Whatever favors rapid and profitable gains with cattle, other than the preparation of the feed, also favors the gains of the hogs following. For example, hogs make better gains following corn-fed steers getting clover, cowpea, or alfalfa hay than they do when the roughage is timothy, millet, or sorghum forage. Likewise feeding the steers linseed meal benefits the hogs that follow. It is almost as profitable to feed tankage or linseed meal to hogs following cattle as to those fattening directly on grain; this is especially true with hogs following cattle fed straight corn with timothy or stover for roughage in winter, or with cattle fattening on corn and bluegrass or timothy pasture in summer.

Waters strongly recommends separate clover or alfalfa pastures accessible to hogs following fattening steers in summer; on these the hogs can graze at will after having cleaned up the waste from the cattle, instead of feeding on the steer pasture. He further recommends providing a field of cowpeas or soybeans on which the hogs may forage early in fall and so have this nitrogenous grain together with the corn they pick up from the steers. Any extra grain fed should be given to the hogs before the cattle are fed so that the hogs will not crowd around the feed troughs or under the wagon and team. In the best practice the hogs are fed in a near-by pen to keep them from the cattle while the latter are feeding. Whenever hogs begin to show maturity or fatness they should be supplanted by fresh ones, for fat hogs are unprofitable for following steers. The best hog for following cattle is of good bone, thin in flesh, weighing from 100 to 150 lbs. If shotes are used they should at least weigh 50 to 60 lbs. Sows in pig or young pigs should never be put in the feed lot.

Because of the narrow margin in fattening cattle, Waters recom-

[2]Mo. Bul. 76.

mends that where it is impossible to provide hogs to follow the steers the fattening of the steers be delayed until hogs can follow or be given up entirely. This advice does not apply to feeding weanling calves for baby beef, because then the grain should be ground and fed with alfalfa, clover, cowpea hay, etc., in which case the animals utilize their feed so much more closely that hogs are not absolutely necessary. (**712, 736**)

804. Frequency of feeding.—According to Mumford,[3] the majority of cattle feeders prefer feeding their cattle grain and roughage twice a day in winter and grain once a day in summer. Feeding once a day in summer is practiced largely as a matter of convenience and not because it is believed to be better for the cattle. For the most part the same reasons that make it desirable to feed grain twice a day in winter apply in summer with equal force.

805. Water.—Fattening cattle should not only have an abundant supply of uncontaminated water at all times, but it should be easily accessible. The water for hogs running in the same lot should be separate and so set off that the steers cannot have access to it, nor should hogs drink from the water troughs of the cattle. While it is best to have water before cattle at all times, they readily adapt themselves to taking a fill once daily and thrive. The water provision should not be less than 10 gallons per day per head for mature cattle.

Georgeson of the Kansas Station[4] kept a record of the water drunk by fattening steers in winter with the following results:

Water drunk by fattening steers in winter

Feed given	Amount of water drunk		
	Daily per steer Lbs.	Per lb. of gain Lbs.	Per lb. of feed Lbs.
Lot I, Corn meal, bran, shorts, oil meal, with hay..	79	33	2.5
Lot II, Corn meal, molasses, and corn fodder.......	73	56	2.4
Lot III, Oil cake, hay..........................	91	57	3.4
Lot IV, Ear corn, corn fodder.....................	56	27	1.8

We note that on the carbohydrate-rich ration of corn and corn fodder the steers drank but 1.8 lbs. of water for each pound of feed eaten, while on the highly nitrogenous ration of oil cake and hay they drank 3.4 lbs., or nearly twice as much. (**103**)

806. Salt.—Animals fed large quantities of rich nutritious food, such as fattening steers receive, show a strong desire for salt, and this craving should be reasonably satisfied. Kühn[5] recommends 1 ounce of salt per day for a steer weighing 1,000 lbs. at the beginning of the fattening period, 1.3 ounces at the middle, and 1.7 ounces near the close. Whether granular or rock salt be supplied is merely a matter of convenience. Some give salt once or twice a week, others keep salt before their cattle at all times. As in other matters of feeding, habit rules, and a plan once adopted should be followed without deviation.

[3]Beef Production, pp. 93-4.
[4]Kan. Bul. 39.
[5]Ernähr. d. Rindviehes, 9th ed., p. 325.

Mumford and Hall of the Illinois Station[6] state that some feeders report favorably on a mixture of equal parts of salt and wood ashes, which the steers eat slowly and with seeming benefit. (**101**)

807. Variations in weight.—Fattening steers show surprising variations in weight from day to day, and even from week to week. Much data could be given on this point, but the following from one of Georgeson's experiments at the Kansas Station[7] will suffice:

Weekly variations in the weight of steers during fattening

Date of weekly weighing	Weight of steer No. 1	Gain or loss	Weight of steer No. 2	Gain or loss	Weight of steer No. 3	Gain or loss
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
November 30	1,232	....	1,190	....	1,207	....
December 7	1,269	37	1,205	15	1,240	38
December 14	1,280	11	1,213	8	1,236	—4
December 21	1,278	—2	1,226	13	1,244	8
December 28	1,325	47	1,250	24	1,270	26
May 2	1,545	....	1,583	....	1,567	....
May 9	1,565	20	1,603	20	1,593	26
May 16	1,597	32	1,620	17	1,619	26
May 23	1,598	1	1,643	23	1,626	7
May 30	1,610	12	1,606	—37	1,593	—33

These variations, which are not extraordinary, show how difficult it is to know the true weight of a steer at any given time. Experiment stations now quite generally weigh the steer for 3 successive days, taking the average as the true weight of the steer on the second day. It has been suggested that the variations follow somewhat the amount of water drunk from day to day, but this explanation does not always seem sufficient. It seems more generally due to the irregular movement of the contents of the digestive tract, which movement is influenced by changes in the character and quantity of the food consumed, the exercise or confinement enforced, and the weather.

808. Cost of fattening.—Mumford[8] gives the following in concise form: "For the purpose of securing a definite basis from which to work, we may assume what has been repeatedly accomplished in practice, that one man and team, or their equivalent, can care for and feed 200 cattle together with the hogs following. This includes not only feeding the grain, but also hauling hay or other roughage to the feed lot from nearby stacks or mows, providing bedding, attending to water, and looking after the wants of steers affected with injuries, lump-jaw, lice and itch. With this assumption as a basis the following statement is possible:

Man, 6 mo. at $40.00 (wages $25, board $15)	$240.00
Team and wagon, 6 mo. at $40 (maintenance $15, feed $25)	240.00
Total cost labor, 6 mo	$480.00
Cost per steer	2.40"

[6]Ill. Cir. 92. [7]Kan. Bul. 34. [8]Beef Production, pp. 33-4.

The returns of hogs following steers fed whole corn will under favorable conditions usually offset the labor cost of caring for fattening steers and the hogs following them. Another reasonable assumption is that when farm-grown crops are charged to the steers at market prices, the labor of feeding them to the cattle is no greater than the labor of hauling them to market.

According to Mumford the manure produced by steers during the 6 months' feeding ranges from 3 to 4 tons, worth, on many farms, from $9.00 to $18.00 per steer. These factors should be considered in counting the cost and returns of fattening steers.

Cotton and Ward of the United States Department of Agriculture,[9] collecting data on 24 Iowa farms where 2,099 cattle were fed in 1909-10 and 1910-11, found that the total cost to the feeder of the fattened steer was distributed percentagely as follows: Purchase price, 57.8; feed, 34.3; interest at 6 per ct., 1.6; labor, 1.7; shipping and selling (not including shrinkage), 4.5 per ct. The proportionate cost of the different items will vary from year to year, especially the first cost of the cattle and the cost of the feed.

809. Preparing for shipment.—Concerning the preparation of cattle for shipment, Clay,[10] than whom there is no better authority, writes: "A day or two previous to shipping, feed the cattle in a pen, and feed hay only. The secret of shipping all classes of cattle is to place them on the cars full of food but with as little moisture as possible. A steer full of water is apt to have loose bowels and show up badly in the yards; properly handled cattle should arrive in the sale pens dry behind and ready for a good fill of water; not very thirsty but in good condition to drink freely. Many shippers think that by salting their cattle or feeding them oats they can fool the buyers, but it always goes against them to use unnatural amounts. As to feed on the road, nothing equals good sweet hay, which excels corn or other grains because it is easily digested and does not fever the animal. Of water in mid-summer, care must be taken to supply the animal wants, whereas in winter a steer can go for many hours without a drink. Cattle should arrive at the sale yards at from 5 to 8 A. M., appearing on the scene as near the latter hour as possible, since they always look better just after they have been fed and watered."

810. Shrinkage.—Extensive investigations in different sections of the United States by Ward of the United States Department of Agriculture[11] show that the shrinkage of range cattle in transit over 70 hours during a normal year is from 5 to 6 per ct. of their live weight. If they are in transit 36 hours or less the shrinkage will usually be 3 to 4 per ct. of the live weight. The shrinkage of fed cattle does not differ materially from that of range cattle for equal periods of time. Silage-fed cattle show a larger gross shrinkage but usually fill so well at market that the

[9] U. S. Dept. Agr., Farmers' Bul. 588.
[10] Live Stock Rpt. Chicago, Sept. 28, 1894.
[11] U. S. Dept. Agr. Bul. 25.

net shrinkage is even lower than with cattle fed no silage. Pulp-fed cattle shrink more than any other class. The difference in shrinkage between cows and steers was not as great as is ordinarily supposed, tho cows shrank somewhat less than steers of the same weight.

When the cattle were fed succulent grass, silage, or beet pulp before being loaded, the shrinkage was great. Slow, rough runs to market naturally increased the shrink. For a long journey the common method of unloading for feed, water, and rest was better than the use of "feed and water" cars. Where cattle reached the market just before being sold, the fill was small, but when they arrived the afternoon of the day before, or about daylight of the sale day, they generally took a good fill. However, an exceedingly large fill at market is not desirable, because buyers then discriminate against such cattle.

811. Fattening cattle requires business judgment.—In fattening cattle, even more than in other lines of animal husbandry good business judgment must be exercised, or the venture is apt to result in loss. Cotton and Ward[12] well summarize some of the important points to be observed by one entering the cattle feeding business:

"Before purchasing his feeders the farmer should estimate the quantity of feeds on hand and their market price, the number and class and size of cattle desired, and the time required to consume the feed. Then he can estimate from market reports the approximate cost of his feeders, and with these various items at hand can figure what they must sell for if he is to break even. He is then in position to select steers which will suit the given conditions. If the outlook is not good, it is usually advisable not to purchase at that time. It is an old adage among stockmen that 'cattle bought right are more than half sold.' A man may be a skillful feeder and lose money year after year because of poor judgment in buying. The beginner should hire some experienced cattleman to purchase animals that will best suit his needs, or deal with a reliable commission firm that is acquainted with his conditions. By following the various market reports the feeder can tell approximately when his cattle can be marketed to greatest advantage. The steers should be fed so as to be finished at that time. When the steers are ready for market, it is usually not advisable to hold for better prices unless they continue to gain in weight and condition. The extra feed consumed by finished cattle will soon more than offset any ordinary increase in price that may be obtained. When they are almost finished the owner should watch the market reports and communicate with his commission man to determine the date of shipment."

The droppings of the steer are an excellent index of the progress of fattening. While they should never be hard, they should still be thick enough to "pile up" and have that unctuous appearance which indicates a healthy action of the liver. There is an odor from the

[12] U. S. Dept. Agr., Farmers' Bul. 588.

droppings of thrifty, well-fed steers known and quickly recognized by every good feeder. Thin droppings and those with a sour smell indicate something wrong in the feed yard. The conduct of the steer is a further guide in marking the progress of fattening. The manner in which he approaches the feed box; his quiet pose while ruminating and audible breathing when lying down, showing the lungs cramped by the well-filled paunch; the quiet eye which stands full from the fattening socket; the oily coat,—all are points that awaken the interest, admiration, and satisfaction of the successful feeder.

812. Order and quiet.—On these important points Mumford[13] writes: "As soon as the fattening process begins, the cattle should be fed at certain hours and in the same way. This cannot be varied 15 minutes without some detriment to the cattle. The extent of injury will depend upon the frequency and extent of irregularity. . . The even-tempered attendant who is quiet in manner and movement invariably proves more satisfactory than the erratic, bustling, noisy one. The cattle soon learn to have confidence in the former and welcome his coming among them, while they are always suspicious of the latter, never feeling quite at ease when he is in sight. Under the management of the former, the cattle become tame and quiet, even tho more or less wild at the outset; while under the latter, wild cattle become wilder and tame cattle become timid. The writer has observed a wide difference in practice among feeders as to their manner of approaching fattening steers. Some are brusque in manner, rushing up to the steers and scaring them up quickly, while other (and I am bound to say more successful) feeders approach the cattle with the greatest care and consideration, getting the cattle up, if at all, as quietly as possible. Pastures for cattle in quiet, secluded places are more valuable for fattening cattle than are those adjacent to the public roads or adjoining pastures where horses or breeding cattle run." (**112**)

813. The eye of the master.—The ability to fatten cattle rapidly and profitably is a gift, to be increased and strengthened by experience and study. The ability to carry a steer through a six months' fattening period without once getting him "off feed" is possessed by many a stockman; but how this faculty is attained is something he cannot well impart to others. In general, when the steer has reached full feed, all the grain he will readily consume should be supplied, but any left in the feed box, to be breathed over, is worse than wasted. Many experienced feeders follow the rule, "Keep the feed always a little better than the cattle." As has been shown (**735**), this means that the preparation of the feed is increased as the fattening progresses. Likewise as the animal advances in flesh there is greater benefit from adding a nitrogenous concentrate, such as cottonseed or linseed meal, to a ration which is already fairly well balanced. (**732**)

Scouring, the bane of the stock feeder, should be carefully avoided,

[13]Beef Production, pp. 92-3.

since a single day's laxness will cut off a week's gain. This trouble is generally induced by over-feeding, by unwholesome food, or by a faulty combination in the ration. Over-feeding comes from a desire of the attendant to push his cattle to better gains, or from carelessness and irregularity in measuring out the feed supply. The ideal stockman has a quick discernment which takes in every animal in the feed lot at a glance, and a quiet judgment which guides the hand in dealing out feed ample for the wants of all, but not a pound excess. Cattle of the same age, or at least those of equal size and strength, should be fed in the same enclosure. Weak animals, and those unable for any reason to crowd to the feed trough and get their share, should be placed where they can be supplied in quiet.

II. Methods of Beef Production

814. Fattening cattle on pasture.—Whether the feeder should finish his cattle during the winter and spring in the dry lot or carry them thru the winter to be fattened on pasture in the summer will depend first of all on the relative cost of pasturage compared with hay, silage, and other roughage. In the grazing regions cattle are commonly sold at the close of the pasture season, when if the grass has been good many are fat enough to be sold as killers, while the rest will go into feed lots to be fattened further. On farms where land is high-priced and there is little waste land the tendency is to fatten feeders in the dry lot, since under these conditions corn silage may be cheaper than pasturage. This is shown in a trial by Bliss and Lee at the Nebraska Station[14] in which one lot of steers were fed on pasture from June 1 to September 10 and another lot given corn silage in a dry lot, both getting a concentrate mixture of 4 parts corn and 1 part cold-pressed cottonseed cake. The steers fed silage made as large gains as those on pasture and only one-fourth as much land was needed to produce the silage as was required for pasture. Mumford and Hall of the Illinois Station,[15] from extensive inquiries in that state, report that cattlemen estimate the daily increase per head of steers during the grazing season at 1.66 lbs. for yearlings and 1.87 lbs. for 2-yr.-olds.

Waters of the Missouri Station,[16] gathering statistics from more than 1,000 successful cattlemen in Missouri, Illinois, and Iowa, found the average gains from cattle pastured for the 6-months period, May 1 to November 1, to be as follows:

Average gain of steers for the 6-months season on grass

State	By yearlings Per month Lbs.	By yearlings Per season Lbs.	By 2-yr.-olds Per month Lbs.	By 2-yr.-olds Per season Lbs.
Missouri	47	282	53	318
Iowa	48	288	52	312
Illinois	45	270	52	312

[14]Nebr. Rpt. 1913. [15]Ill. Cir. 79. [16]Mo. Cir. 24.

Assuming a pasture charge for yearlings of 75 cents per month, their gains cost approximately $1.60 per 100 lbs., while the 2-yr.-olds at a pasture charge of $1 per month would put on gains costing but little over $1.90 per 100 lbs. When we reflect that gains made by steers in winter cost from $6 to $10 per 100 lbs. the importance of wisely and fully utilizing the pastures in summer is apparent.

Skinner and Cochel of the Indiana Station[17] found thru extensive inquiry that in Indiana during summer feeding each grain-fed steer grazed over 1.1 acres of land on the average. Where no grain was given, each steer grazed over about 2 acres.

Lloyd of the Mississippi Station[18] reports that 2-yr.-old heifers, fed a light ration during the winter, when turned to pasture gained 1.3 lbs. each daily for 178 days on pasture alone. Steers of the same age, thin in flesh when turned to pasture, made daily gains of 1.4 lbs. for 178 days, while those full fed the previous winter gained but 0.8 lb. each day during 158 days.

815. Summer vs. winter feeding.—Waters of the Missouri Station[19] reports the gains in 3 summer and 5 winter feeding trials as follows:

	Summer	Winter
Number of animals	88	105
Average length of feeding period, days	209	107
Concentrates per 100 lbs. of gain, lbs	814	999
Roughage per 100 lbs. of gain, lbs	grass	382
Average daily gain per steer, lbs.	2.37	2.13

Because of the longer feeding period the summer-fed cattle were much fatter than those fed in winter. Despite this the summer gains were made on 18.5 per ct. less grain.

Mumford and Hall of the Illinois Station,[20] from extensive correspondence with feeders of their state, conclude that a bushel of corn will produce:

	Gain in winter feed lot	Gain in summer on pasture
With calves	8.9 pounds	10.0 pounds
With yearlings	6.5 pounds	7.6 pounds
With 2-yr.-olds	5.4 pounds	6.8 pounds

Waters[21] sets forth the following advantages of fattening on pasture compared with finishing cattle in the dry lot:

Grass is cheaper than hay.

Summer gains require less grain than winter gains.

Steers fatten more quickly and can be made thick and prime on corn and grass with greater certainty, more uniformity, and the smaller use of expensive supplements like cottonseed meal and linseed meal.

Hogs following the steers make larger gains, and return more profit, with a lower death rate.

In summer the grain only is drawn; there is no roughage to handle.

The steers are usually fed but once daily.

The manure is scattered by the cattle themselves.

816. Feeding concentrates on pasture.—When cattle are finished on pasture no concentrates at all may be fed, a small allowance may be

[17]Ind. Cir. 12. [18]Miss. Rpt. 1903. [19]Mo. Bul. 76. [20]Ill. Cir. 88. [21]Mo. Cir. 24.

given during the entire pasture period, concentrates may be fed during only the last few weeks, or an unlimited allowance of grain may be given thruout the entire period. Except under range conditions and in certain districts, as in the bluegrass region of Virginia, where the pastures are unusually nutritious, it will usually pay to feed some grain in addition to pasture. As Waters[22] points out, the cheapness of gains on grass alone is offset by the low selling value of the cattle, because they are not usually fat enough to market and must be sold as feeders with sufficient margin for the buyer to profitably fit them for market.

817. Feeding supplements with corn on bluegrass pasture.—During 5 years Mumford conducted extensive trials at the Missouri Station[23] with high-grade beef steers of various ages to study the economy of feeding a nitrogenous supplement to animals full fed on corn and running on a good bluegrass pasture. In these trials a total of 126 yearlings, 55 two-yr.-olds, and 51 three-yr.-olds were fattened. Each year the steers were turned to pasture May 1, and fed for 7 months, by which time the 2-yr.-olds and 3-yr.-olds were finished while the yearlings in every instance required feeding for 40 to 60 days longer. The results secured in these trials are summarized in the following table:

Feeding supplements with corn to steers on bluegrass pasture

	Corn alone	Corn and linseed meal	Corn and cottonseed meal	Corn and gluten feed
Yearlings, av. of 5 years				
Av. daily concentrate allowance, lbs.	15.8	17.2	16.5	16.5
Av. daily gain, lbs.	2.0	2.2	2.2	2.2
Concentrates per pound gain, lbs.	7.78	7.76	7.67	7.64
Feed cost per 100 lbs. gain*	$6.55	$7.21	$7.09	$6.98
Two-yr.-olds, av. of 2 years				
Av. daily concentrate allowance, lbs.	20.1	20.4	21.0	.....
Av. daily gain, lbs.	2.5	2.7	2.6	.....
Concentrates per pound gain, lbs.	7.98	7.64	7.97	.....
Feed cost per 100 lbs. gain*	$6.71	$7.09	$7.14	.....
Three-yr.-olds, av. of 2 years				
Av. daily concentrate allowance, lbs.	23.1	24.9	23.7	.....
Av. daily gain, lbs.	2.3	2.8	2.5	.....
Concentrates per pound gain, lbs.	10.13	8.77	9.85	.....
Feed cost per 100 lbs. gain*	$8.38	$7.96	$8.39	.....

*Shelled corn, 40 cents per bu.; linseed meal, $28; cottonseed meal, $24; and gluten feed, $22 per ton; pasture—yearlings, 60 cents, and older cattle, 75 cents per month.

Since immature grass, such as is usually eaten by grazing animals, is much richer in protein than grass at the stage when cut for hay, corn and bluegrass pasture alone make a fairly well-balanced ration for the fattening steer. (800) Adding a nitrogenous concentrate, however, increased both the consumption of feed and the rate of gain with all the ages. With the exception of the 3-yr.-old steers fed corn and linseed meal, the lots receiving the supplements required about as much feed per pound gain as those fed corn alone, and with feed at the prices given

[22] Mo. Bul. 76. [23] Mo. Bul. 90.

made more expensive gains. With the yearlings and 2-yr.-olds the greater feed-cost of the gains when a supplement was fed was, however, offset to a greater or less extent by the fact that the steers fed the supplements showed better finish at the close of the trial and would therefore sell for a higher price. The difference in gains between the steers fed corn alone and those receiving a supplement was greatest toward the close of the trial and with steers which were in the best flesh. Mumford concludes, "The results of our experiments for many years and with various rations and kinds of cattle clearly indicate the value of supplements in maintaining the appetite and in securing satisfactory gains during the last stages of the feeding period. The value of supplements during the first part of the feeding period has in many experiments been of doubtful economic value." Obviously the higher the price of corn compared with the cost of the supplements, the greater the advantage from their use. While cottonseed meal gave slightly better returns with the yearlings than did linseed meal, the results were reversed with the older cattle.

818. Hints on fattening cattle on pasture.—Care should always be taken in changing cattle from dry lot to pasture, especially where they are in good flesh, else they may not continue to gain or may even shrink severely. As young pasture grass is laxative, if silage or roots have been fed during the winter the allowance should be reduced or entirely withdrawn as soon as the cattle are turned to pasture. Dry roughage which is palatable should be fed during the change, for otherwise the cattle may refuse the dry feed, preferring the grass. When the cattle are turned to pasture early in the season and there is no dry grass standing over from the preceding fall, it is wise to leave them on pasture for only a short time the first day and increase the period gradually, else severe scouring may result. If grain has been fed during the winter it should be continued until the cattle are accustomed to grass. Where cattle are nearly finished by the time the pasture season opens they had best be finished in the dry lot, for if turned to pasture they will usually make much poorer gains. Shaw[24] recommends that cattle be kept from pasture unless they are to be fed at least 2 months before being marketed.

When the corn crop matures before the cattle are finished for market they may be turned into the standing corn, hogs following to get the corn not eaten by the steers. Where this practice is followed the cattle should be accustomed to new corn by being fed gradually increasing amounts of new snapped, or ear corn, or corn fodder before being turned into the corn field.

819. Baby beef.—The most intensive method of beef production is the fattening of calves as baby beef. Under this system beef calves are fattened as they grow, reaching a good finish when 16 to 18 months old and weighing about 1,100 lbs. or less. In the production of baby beef,

[24]The Management and Feeding of Cattle, p. 174.

first of all, blocky calves of good beef type and conformation must be selected, for scrub or dairy-bred calves will not usually reach the desired maturity and finish at this early age. As Mumford[25] writes, profitable baby beef production requires experience, judgment, and skill of the highest order in the feeder. It is a mistake for the inexperienced to dip heavily into this art. To fatten young animals profitably, they must be good, they must be fed for a considerable time, and they must be made fat; this means that "tops" must be bought or bred. The most successful operators try to retain the "calf fat" or bloom of the young calf. The calf should be in good condition when fattening begins and should be induced to consume considerable roughage of high quality, such as clover or alfalfa hay and silage, during winter and rich pasture grasses in summer. Shelled, crushed, or ground corn should be fed together with linseed meal, cottonseed meal, or other protein-rich concentrates. If the corn is given whole, hogs may profitably follow. Oats are one of the best of feeds with which to start the calf on its way to fattening. The tendency of the calf and yearling is toward growth rather than fattening. In baby beef production the young things must fatten as they grow; this can only be accomplished by the most liberal and judicious feeding, since it is extremely difficult to get calves and yearlings sufficiently fat for the market requirements. Heifer calves mature more quickly and may be marketed earlier than steers. It is seldom possible or profitable to get spring calves ready for the baby beef market before July of the following year; more frequently they are not marketed until October, November, or December when approximately 18 months old.

This system of beef production is best suited to corn-belt farms where pasture is relatively expensive, while corn is cheaper in price than in other sections of the country. (711-2)

820. Economy of gains of calves fed for baby beef.—At the Kansas Station[26] Cottrell, Haney, and Elling placed 130 calves, just weaned, in the feed lot during the latter part of October. Sixty were grade Shorthorn, Hereford, and Angus range heifers. The rest were purchased locally or raised at the college farm. All were fed twice daily, getting all the grain and roughage they would clean up within 3 hours after feeding. They were sheltered by a common board shed open to the south and were fed for 7 months with the results shown below:

Feed and 7-months' gain of calves fed for baby beef

Feed given	Av. gain per head	Feed for 100 lbs. gain	
		Concentrates	Roughage
	Lbs.	Lbs.	Lbs.
Lot I, Alfalfa hay and corn	407	470	544
Lot II, Alfalfa hay and kafir	379	524	626
Lot III, Prairie hay, corn ⅔, and soy beans ⅓	378	520	486
Lot IV, Prairie hay, kafir ⅔, and soy beans ⅓	342	594	539
Lot V, Skim-milk calves—alfalfa hay and corn	440	439	436
Lot VI, Whole-milk calves—alfalfa hay and corn	404	470	420
Average	392	503	509

[25] Beef Production, pp. 76-82. [26] Kan. Bul. 113.

The surprisingly small amount of feed for 100 lbs. of gain will be noted. By the end of the following May, when from 12 to 14 months old, the entire lot averaged 800 lbs. in the college feed lot, and on shipping to Kansas City shrank 3 per ct.

821. Fattening yearlings.—Less extreme than the feeding of calves for baby beef is finishing steers as yearlings, i.e., before they are 2 years old. Spring calves may be carried thru the first winter on roughage with but a small allowance of concentrates. However, the ration must be such as to keep them growing steadily. The second summer good pasture alone will be sufficient to put them into condition for the feed lot in the fall.

Calves to be fattened as yearlings should be taught to eat grain before being weaned so that there may be no loss of condition at this time. Yearlings can hardly be finished in a 6-months winter feeding period, but require fattening for 8 to 10 months even if of good beef type. Skinner and Cochel conclude from 3 years' trials at the Indiana Station[27] that it is ordinarily more profitable to complete the fattening in the feed lot, rather than turn the half-finished cattle out to grass in the spring, for larger and cheaper gains are thus made. (**711-2**)

822. Fattening cattle 2 years old or older.—Where pasturage is cheap, cattle are usually not marketed until 2 years old or older. They may be carried thru the first winter chiefly on roughage, or even entirely, if fed legume hay and other roughage of good quality. (**799**) On good pasture they will make good growth the following summer. If they are to be finished on grass early the third summer they will need a moderate allowance of concentrates the second winter. If to be sold in the fall or after finishing in the feed lot, little or no grain will be required provided good quality roughage is fed.

According to Cochel,[28] the system of beef production usually most profitable in western Kansas is to raise the calves on pasture the first summer, winter them on kafir, milo, or sorghum silage, alfalfa hay and straw or stover from the sorghums, with perhaps some cottonseed meal in addition, pasture the yearlings the second summer without feeding grain, carry them thru the second winter as before, and market the third summer from grass. With good pasture such cattle should reach a weight of about 1,050 lbs. and be fat enough to sell as fleshy feeders or fair killers. In other sections of the western grazing district a still more extensive system is yet followed, the steers not being sold until 3 years of age. However, the tendency is ever toward hurrying the steer to the block, and while 4- and 5-yr.-old steers were once common on the range, but few now reach this age.

[27] Ind. Bul. 142.

[28] Information to the authors.

CHAPTER XXX

GENERAL PROBLEMS IN SHEEP HUSBANDRY

The sheep is the plant-scavenger of the farm. Because of its dainty manner of nibbling herbage we might suppose that its likes were few and dislikes many, yet nearly every plant at some period of its growth seems palatable and is freely eaten. No domestic or wild animal is capable of subsisting on more kinds of food. Grasses, shrubs, roots, the cereal grains, leaves, bark, and in times of scarcity fish and meat, all furnish subsistence to this wonderfully adaptive animal. In the great pine forests of Norway and Sweden[1] they will exist thru a hard winter by eating the pungent resinous evergreens. Among the Laplanders, when other foods fail, they eat dried fish, the half-rotten flesh of the walrus, or even the very wool off each others' backs. Low[2] reports that the sheep of the Shetland Islands feed upon the salty seaweed during winter, knowing by instinct the first ebbing of the tide, and that they are fed dried fish when normal foods are scarce.

McDonald[3] writes of the Iceland sheep: "The only kindness which these animals receive from their keepers in the winter is being fed on fish-bones and frozen offal, when their natural food is buried too deep even for their ingenuity and patience."

While sheep may exist under such conditions, we can expect good returns only when they are given proper feed and care.

823. Place of sheep on the farm.—The organs of mastication and digestion indicate that plants in some form constitute the natural food of sheep. The cutting teeth in the lower jaw fit against the cartilaginous pad above in such manner that, when feeding, the herbage is torn off rather than cut. While horses and cattle eat only about half the plants considered weeds, less than one-tenth are refused by sheep. They even prefer some weeds, when yet succulent, to the common grasses. Sheep graze more closely than other stock, and if many are confined to one field every green thing is at length consumed. When closely pastured on cut-over timber lands where the growth is not too rank they derive much nourishment from the leaves, bark, and twigs, destroying the brush nearly as effectively as goats. (**3**) The feces of the sheep show the finest grinding of any of the farm animals, and as they relish most weed seeds this further fits them as weed destroyers. As sheep graze, their droppings are distributed more uniformly than with other stock. At nightfall they instinctively seek the higher, usually poorer, land and

[1]Sheep Husbandry, Killebrew, p. 6.
[2]Domestic Animals of the British Islands.
[3]Cattle, Sheep and Deer.

thus leave their droppings on areas where most needed. Thru increasing the fertility of the pastures it grazes, the sheep has won the title of "The Golden Hoof."

Only a relatively small investment is necessary to start in sheep husbandry, since the foundation animals cost but little and the flock increases rapidly. Sheep require neither expensive barns nor implements and only the minimum of care and attention during the busy summer season. In wool and in the flesh of her off-spring, the ewe gives double returns each year. With fair prices, the wool pays for her maintenance, leaving as profit all income from the lamb or lambs, after deducting the small cost of the additional feed and care they require. Returns come quickly, as lambs may be marketed 8 or 9 months after the ewes are bred. While surpassed by the pig in economy of meat production, the lamb requires less feed per pound of product than the steer. Because sheep readily consume food which would otherwise be wasted a flock will prove profitable on many farms where most of the revenue is derived from other sources. On rough or hilly land that cannot be economically tilled sheep may often be the main live stock of the farm. Tho the cost of maintenance is lowered thru their utilization of otherwise waste feed, one must not expect profitable production from such feed alone.

824. Mutton breeds and Merinos compared.—The Merino sheep is peculiarly a wool-bearer, and nearly all lines descended from the Spanish stock have been selected for that single purpose. The story of the Spanish Merino in its home country forms one of the most interesting chapters in the history of live stock.[4] In their pilgrimage from South to Central Spain each spring and their return in the fall the great Spanish flocks made annual journeys covering over a thousand miles. Only the strongest and most rugged survived the long, fatiguing, perilous marches. The ability to exist in enormous flocks, to range over a vast territory, and to subsist upon scant food are the leading of the many remarkable qualities wrought by stern Fate into the very constitution of the Merino sheep.

Almost opposite in several characteristics are the English mutton breeds, which have been reared in small flocks confined to limited pastures, the best specimens being saved and nurtured each year with intelligent attention to all their wants. They have been sheltered from storms and liberally fed with rich roughage and grain in the sheepfold whenever the fields were scant of herbage or the weather severe. In general the life of the English mutton sheep has been one of quiet contentment and plenty almost to surfeit. In this country we cannot hope to attain the wonderful success reached by British flockmasters unless we closely follow or improve upon their methods.

825. Size of the flock.—The sheep is distinctly gregarious. The improved American Merino still shows the result of inheritance in its ability to exist in great flocks and thrive under the most ordinary conditions of care and keep. With reasonable oversight thousands of Me-

[4] Low, Domestic Animals of the British Islands, Vol II.

rino sheep can be held in single bands where the range is ample, and for the brief period of fattening tens of thousands may be successfully fed together, as is still done with range sheep, carrying Merino blood, which are brought to feeding points in the western states and in the Mississippi valley.

In the humid regions, two hundred sheep of the mutton breeds are as many as can usually be successfully managed in one flock, and to secure the best returns from even this number one should have had previous experience. The novice would better begin with a flock of 25, increasing the number as experience grows. When the farm is heavily stocked with sheep, increased vigilance is needed to prevent infestation with internal parasites and other troubles which are sure to threaten.

826. A breed test.—Wilson and Curtiss[5] at the Iowa Station fattened wethers of different breeds on the same rations in 2 trials, lasting 90 and 105 days, respectively, with the results averaged in the table. In the first trial there were ten 12-months-old wethers in each lot and in the second 9, averaging 9 months of age. National Delaine Merinos were used in the first trial and Rambouillets in the second.

Comparison of breeds for mutton and wool production

	Av. wt.	Av. daily gain	Av. total gain	Feed for 100 lbs. gain			Per cent dressed carcass	Av. wt. of fleece	Value of fleece
				Grain	Hay	Roots			
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Dollars
Southdown.....	78	0.40	39.2	483	451	279	55.3	5.7	0.70
Shropshire......	95	0.41	40.6	500	476	306	54.6	8.3	1.04
Dorset..........	92	0.45	44.8	485	494	286	53.4	6.4	0.80
Suffolk..........	105	0.47	46.3	492	493	280	53.1	6.4	0.81
Oxford..........	107	0.46	45.2	499	500	311	52.6	9.5	1.30
Leicester........	109	0.48	47.2	465	462	293	54.8	10.3	1.54
Cotswold........	102	0.55	54.5	418	411	249	54.2	11.3	1.56
Lincoln.........	108	0.50	49.7	457	451	270	53.4	11.7	1.67
Merino..........	78	0.32	32.4	573	509	345	50.7	8.2	0.87

The large breeds—Leicester, Cotswold, and Lincoln—made somewhat the largest daily gains, the Merinos ranking lowest and consuming the most feed for 100 lbs. of gain.

827. Breeds for crossing on western ewes.—To learn the value of the various crosses on western ewes, Wilson[6] of the South Dakota Station divided 60 Montana-bred yearling ewes into 6 lots, breeding each lot to an average-quality ram of one of the breeds shown in the table. The experiment ran 6 years, each lot being bred in successive years to a ram of each of the 6 breeds. The lambs were grazed on bluegrass and rape pastures until freezing weather in the fall, and then fattened on a grain mixture of 100 lbs. shelled corn, 100 lbs. oats, and 25 lbs. linseed meal, with all the upland prairie hay they would eat. They were shorn before marketing in the spring. During the course of the experiment, some of the ewes in each lot were lost from various causes.

[5]Iowa Buls. 33, 35. [6]S. D. Bul. 127.

Value of rams of various breeds for crossing on western ewes

Breed of ram	No. of lambs fed	Initial weight Lbs.	Daily gain Lbs.	Concentrates for 100 lbs. gain Lbs.	Valua of wool per head Dollars	Dressed carcass* Per ct.
Cotswold.........	55	77	.36	524	1.63	52.4
Oxford...........	53	82	.34	543	1.36	52.9
Hampshire........	55	80	.31	587	1.37	53.4
Shropshire........	57	73	.31	575	1.36	53.2
Southdown.......	53	72	.25	564	1.11	53.1
Rambouillet......	53	72	.31	563	1.24	54.2

*Average of 3 years.

The Cotswold lambs made the largest and most economical gains and led in value of fleece. In percentage of dressed carcass the Cotswolds were the lowest and the Rambouillets the highest. The general criticisms before slaughter were that the Cotswolds were too leggy and heavy, the Hampshires and Oxfords too heavy, and the Rambouillets not smooth enough. The Southdowns and Shropshires best met the demands of the market.

Faville,[7] at the Wyoming Station, mated 29 fine-wooled western ewes with a good Cotswold ram and another lot with a Southdown ram, and fattened the resulting lambs. The Cotswold grades made slightly larger and more economical gains, but the Southdowns gave a higher percentage of dressed carcass, worth more per pound. Carlyle and Iddings,[8] on fattening a lot of 139 Lincoln-Merino lambs and 161 Shropshire-Merinos at the Idaho Station, found that the latter made slightly larger gains, while the feed consumed per 100 lbs. gain was practically the same for both lots.

828. Feeding grain before and after weaning.—At the Wisconsin Station,[9] Craig studied the profitableness of feeding grain to lambs before and after weaning when on good pasture. In 4 trials high-grade Shropshire lambs, early induced to eat various grains, were given all they would consume in a trough placed in a lamb-creep. (**894**) The following table summarizes the results secured before weaning, in periods averaging 10 weeks:

Feeding various grains to lambs before weaning

Average daily grain allowance	Initial weight Lbs.	Daily gain Lbs.	Total gain Lbs.	Concentrates for 100 lbs. gain Lbs.
Lot I, Corn meal, 0.4 lb.*............	39	0.51	35.8	74
Lot II, Whole oats, 0.4 lb.............	44	0.53	37.0	78
Lot III, Wheat bran, 0.3 lb............	43	0.48	33.6	71
Lot IV, Cracked peas, 0.4 lb..........	37	0.53	37.0	81

*Average of 5 trials.

The large daily gain of over one-half pound made by these unweaned lambs and the small concentrate requirement in addition to the dam's milk forcefully illustrate the great general principle that young, growing animals give the best returns for feed consumed. All the different concentrates fed were found satisfactory. Corn fed alone gave good

[7] Wyo. Bul. 95. [8] Idaho Bul. 77. [9] Wis. Rpts. 1896, 1903.

returns, especially when cost was considered, the dam's milk supplementing this highly carbonaceous grain. From these and other careful studies, Craig reached the following conclusions:

"The continuous grain feeding from birth until the lambs were about 10 months old did not produce any noticeable difference in the carcasses in respect to the mixture of fat and lean, but materially influenced the early maturity of the lambs. The lambs so fed attained a given weight from 4 to 7 weeks sooner than those fed no grain before weaning and required about the same amount of grain for the same increase in weight. When lambs are fed grain continuously from birth they are fit for the market at any time, so that advantage may be taken of any favorable fluctuation that may occur in prices. When the lambs are to be sold at weaning time in July at the age of 3 or 4 months, or in November when about 7 months old, it will pay to feed them grain."

The unlimited feeding of grain after weaning led the lambs to eat less pasture. One-half pound of grain per head daily is the greatest amount that was found profitable to feed at this time.

829. Soiling ewes and lambs.—Because of their daintiness and the large variety of plants they crop if opportunity offers, it is usually undesirable to maintain sheep on soilage. However, desiring to ascertain, regardless of cost, the amount of food required by sheep for growth in summer, the senior author[10] conducted the following trial at the Wisconsin Station. Ten large Merino ewes were chosen, each with a vigorous lamb at foot 1 month old when the trial began, June 3. With patience and laborious attention to details the shepherd fed the lot successfully, obtaining the results given in the table:

Feed required for 100 lbs. gain when soiling ewes and lambs

	Green clover Lbs.	Green corn fodder Lbs.	Hay Lbs.	Oats Lbs.	Total dry matter Lbs.
Ewes and lambs before weaning, 106 days	1,806	1,366	...	45	850
Lambs after weaning, 28 days	....	915	292	413	806

When we remember that the ewes and lambs would have preferred to do their own foraging the amount of dry matter required per 100 lbs. gain was most reasonable. When we further consider that, if allowed to graze, they would have eaten weeds and weed seeds as well as the better forage, we must conclude that the sheep is one of the most economical meat producers on the farm.

830. Shearing lambs before fattening.—From trials covering 4 years at the Wisconsin Station[11] Craig found that fall shearing, not later than October, was beneficial from the standpoint of size and economy of gains, when lambs that were 6 months old were to be prepared for the early winter market. With lambs fattened during a 3 or 4 month winter period no advantage resulted. Tho more wool was obtained by shearing in

[10] Wis. Rpt. 1890. [11] Wis. Rpt. 1904.

the fall and again in the spring, the market value of the 2 clippings was no greater than the single clip with its longer fibers.

In a 13-week trial by F. B. Mumford at the Michigan Station,[12] a lot of 10 lambs was shorn in November while another was left unshorn, both being fattened on a ration of clover hay and equal parts of corn and wheat. Both lots were kept in a barn, the window in the pen containing the unshorn lambs being left open, while that in the pen of the shorn lambs was kept closed. Despite this care, the shorn lambs suffered from the cold. The shorn lambs ate 0.1 lb. more grain and 0.2 lb. more hay per head daily, yet made 30 per ct. less gain than those not shorn. Had the shorn lambs still warmer quarters, there undoubtedly would have been less difference in the returns.

On account of the prevalence of the practice of shearing lambs before fattening when they are to be fed late in the spring, Skinner and King fed 166 lambs for 60 days, beginning March 14, at the Indiana Station.[13] Half were shorn when they had been on feed 10 days while the others carried their wool till 10 days before the close of the trial. The early-shorn lambs made neither larger nor more economical gains than the others. Undoubtedly if the weather grows very warm in the spring before lambs are finished, it will pay to remove their fleeces.

831. Fattening sheep of different ages.—At the Montana Station[14] Shaw compared the fattening qualities of average western range lambs, 1- and 2-yr.-old wethers, and aged ewes. Each lot of about 50 was fed whole barley and clover hay for 88 days with the following results:

Fattening range sheep of different ages

Age when fed	Average ration Barley Lbs.	Average ration Clover hay Lbs.	Av. wt. at beginning Lbs.	Av. daily gain Lbs.	Av. total gain Lbs.	Feed for 100 lbs. gain Barley Lbs.	Feed for 100 lbs. gain Clover hay Lbs.
Lambs	0.7	2.1	63	0.27	23.7	253	763
One-year-old wethers	0.7	3.8	95	0.27	23.5	256	1,413
Two-year-old wethers	0.7	4.1	116	0.28	24.3	248	1,469
Aged ewes	0.7	2.3	92	0.18	15.6	387	1,320

It will be observed that all lots, except the aged ewes, made practically the same daily and total gains. All were fed the same amount of grain, but the lambs ate only about half as much hay as the yearlings or 2-yr.-olds. Hence the gains of the lambs were much more economical. In other trials at the same Station,[15] lambs made not only more economical but also more rapid gains than yearling wethers. It is generally unwise to feed yearlings for the block, since they are shedding teeth and therefore not in condition to give the best returns for feed and care. Unless prices for wool rule high the stockman cannot afford to carry wethers past the period when they may be fed off as lambs. Culls can be prepared for the butcher at any time by the use of a little grain. In the vicinity of cities profitable sales can be made of fat culls at times when regular feeders have failed to supply the market.

[12] Mich. Bul. 128. [13] Ind. Bul. 168. [14] Mont. Bul. 35. [15] Mont. Buls. 47, 59.

The demand for well-fattened lambs grows, the tender, juicy, high-flavored meat finding increasing favor among Americans. Not only do prices for fat lambs rule high as compared with mature sheep and farm animals generally, but there are other advantages in feeding off lambs before they reach maturity. A given weight of feed goes further with lambs than with mature sheep; the money invested is sooner turned, and there is less risk from death and accident. Thus the tendency is toward marketing the lambs as rapidly as they can be satisfactorily sold. If lambs raised on farms are not sufficiently fat in late summer or early fall to meet the reasonable demands of the market, it shows a lack of feed and care, or that parasites have destroyed profits. Owing to their tendency to grow, lambs require a longer period to fatten than do mature wethers. Since they are not only making fat but also lean meat, the ration should be somewhat narrower, that is, contain more protein, than is needed for fattening mature sheep. However, a ration which is too narrow will unduly stimulate growth, and not give the requisite finish.

832. Shelter for sheep.—Above every other animal on the farm the sheep should be kept dry as to both coat and feet. Inattention to either of these essentials will result disastrously. With dry winter quarters sheep will stand a great degree of cold without injury. Their shelter should not be warm, compared with that of other farm animals, for sheep sweat badly in winter when confined in quarters sufficiently warm for dairy cows. One thickness of matched boards will make the barn or shed where sheep are confined sufficiently warm in the northern states except for winter lambs. Ample ventilation is of great importance, but drafts must be avoided. On the western plains, it is even more necessary to protect sheep from cold winds than from rain. Sunshine, good drainage, and conveniences for feeding are the other requisites of a good sheep barn. When succulent feeds, such as wet beet pulp or silage, are fed the quarters must be especially well drained and the barn or shed well bedded. Stone basements are unsatisfactory for sheep on account of dampness, and if used good ventilation is especially necessary. Damp walls are a sure indication of lack of ventilation and impending trouble.

In late spring and early summer when cold rains begin, the flock should be sheltered if possible, for exposure is dangerous, especially to young lambs. In the heat of summer if there is no natural shade in the pastures the flock should have access to a darkened but well ventilated shed. A fringed curtain thru which the sheep force their entrance will keep back the flies from this retreat. (881)

833. Winter quarters for fattening sheep.—At the Minnesota Station[16] Shaw fed eight 78-lb. lambs for 117 days in a yard sheltered from the wind by a low building at one side. A second lot was confined in a yard with an open shed for shelter, while a third was kept in a compartment of a barn ventilated by means of a large window facing the east. All lots were fed the same ration with the following results:

[16]Minn. Bul. 44.

Effect of various methods of confinement on fattening lambs

Where fed	Average daily gain Lbs.	Feed for 100 lbs. gain: Wheat screenings Lbs.	Oil meal Lbs.	Hay Lbs.
Lot I, out of doors	0.28	804	90	316
Lot II, in yard with shed	0.32	668	74	251
Lot III, in stable	0.28	722	80	283

Lot II, kept in a yard with an open shed, made the largest and the most economical gains, while Lot I, kept out of doors, made as good gains as those confined in the barn, but required slightly more feed for 100 lbs. of gain.

Skinner and King found at the Indiana Station[17] that lambs fattened during the winter in an open shed and adjacent yard made 0.01 lb. less daily gains and required slightly more feed for 100 lbs. gain than others kept in a well-ventilated barn. But the lambs in the open shed were better finished, and sold for enough more to overbalance the slightly higher cost of gains. In a later trial the lambs fed in the open shed consumed less feed per 100 lbs. gain and again sold for a higher price than those fed in the barn.

That shelter from rain is needed even in a moderate climate is shown in a trial by Mumford, Trowbridge, and Hackedorn at the Missouri Station[18] in which yearling wethers fed in an open yard made smaller gains and required over 19 per ct. more feed per 100 lbs. gain than others which had access to a barn. In the northern states a dry, littered yard, having a sunny exposure, and provided with a well-bedded, comfortable shed opening to the east or south, extending along the windward side to break the cold winds and driving storms, is ideal for fattening sheep. In such quarters the air is bracing, the sunshine invigorating. Here the animals, heavy coated and filled with rich grain and roughage, are both warm and comfortable, and comfort is essential to the highest gains. In the arid regions, protection from driving winds and sandstorms is all that is essential.

834. Exercise.—For the breeding flock abundant exercise thruout the year is essential. (**111**) That fattening sheep make better gains if allowed but limited exercise is shown by trials at the Wisconsin Station[19] in which during 3 consecutive winters Humphrey and Kleinheinz kept one lot of 12 wether lambs in a dry, airy, well-lighted pen during fattening while another was turned out daily for exercise when the weather permitted. The results are averaged in the following table:

Exercise vs. confinement for fattening wether lambs

	Average ration: Grain Lbs.	Hay Lbs.	Roots Lbs.	Av. daily gain Lbs.	Feed for 100 lbs. gain: Grain Lbs.	Hay Lbs.	Roots Lbs.
Exercised	1.1	1.9	1.4	0.15	708	1,297	1,068
Not exercised	1.1	1.9	1.4	0.17	618	1,113	899

[17] Ind. Bul. 168; information to the authors.

[18] Mo. Bul. 115. [19] Wis. Rpts. 1904-05.

In no case did these lambs make large or economical gains, for they were in better condition at the beginning than average feeder lambs and were not forced for the largest gains. The lambs given exercise made slightly smaller gains and required over 16 per ct. more feed for 100 lbs. gain than those more closely confined.

835. Grinding grain; cutting or grinding hay.—Of all farm animals the sheep is best able to do its own grinding, and with few exceptions whole grain only should be furnished. (**423**) The common saying of feeders, "a sheep which cannot grind its own grain is not worth feeding," is a truthful one. Valuable breeding sheep with poor teeth may be continued in usefulness by being fed ground grain. In certain cases grinding may prove advantageous. At the Colorado Station[20] Cooke, when feeding western sheep on wheat, observed that much of the grain passed thru the animals unbroken. As shown in the next chapter, it is well to grind such hard seeds as bald barley, millet, and screenings containing small weed seeds.

From 4 trials testing the value of cutting and grinding alfalfa hay for fattening lambs, Morton of the Colorado Station [21] concludes that when good quality long alfalfa hay is fed not enough is refused to warrant such preparation. When poor quality hay is used, cutting into three-fourth inch lengths may be profitable thru inducing closer consumption, provided the cost is not more than $1 per ton. Reducing such hay to meal may be warranted, if the cost is not more than $3 to $4 per ton.

836. Self feeders; feed racks.—To save time and labor some feeders place quantities of grain sufficient for a week or more in a self feeder, a box so arranged that the grain passes down into the feed trough as rapidly as the sheep consume the supply below. Trials with self feeders by F. B. Mumford at the Michigan Station[22] with ten 80-lb. lambs in each lot, fed for 105 days, and by Shaw at the Minnesota Station[23] with eight 80-lb. lambs in each lot, fed for 117 days, are summarized in the table:

Trials with self feeders for fattening lambs

Method of feeding	Average ration		Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
	Grain	Hay			Grain	Hay
Michigan		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Self-fed	Corn, 1.4 lbs.	0.9	0.23	24.8	607	387
Ordinary	Corn, 1.5 lbs	1.0	0.31	32.8	481	334
Self-fed	Corn and bran, 1.8 lbs	0.9	0.22	23.7	776	405
Ordinary	Corn and bran, 1.6 lbs	1.0	0.25	26.7	638	421
Minnesota						
Self-fed	Wheat screenings, 3.2 lbs	0.5	0.35	41.6	908	130
Ordinary	Wheat screenings, 2.4 lbs	0.8	0.32	37.5	742	251

[20] Colo. Bul. 32.
[21] Colo. Buls. 151, 187.
[22] Mich. Bul. 113.
[23] Minn. Bul. 44.

In each trial the self feeder increased the feed consumed for 100 lbs. of gain. Mumford[24] concludes from tests covering 3 years, "Fattening lambs by means of a self feeder is an expensive practice, and economy of production requires more attention to the variation in the appetites of the animals than can be given by this method." After a later trial with yearling wethers at the Missouri Station[25] Mumford writes, "The advantage of a self feeder even at a low price of corn is small, as it will be found necessary to feed by hand the first 5 or 6 weeks of the feeding period in order to accustom the sheep to a full feed of grain before them all the time." Numerous observations show that the death rate is higher when self feeders are used. The more concentrated the grain, the greater the danger in feeding it thru the self feeder. Bulky wheat screenings have been satisfactorily fed in self feeders.

From trials during 2 years Morton[26] reports that under Colorado conditions, with lambs fattened in the open, self-feed hay racks, costing $1 per running foot and accommodating 4 lambs per foot, 2 on a side, saved sufficient hay, compared with feeding it on the ground outside the pens, to pay their cost in 3 seasons. It is well to construct hay racks so that chaff and seeds will not fall upon the necks of the sheep, since such material will work down into the wool, injuring its quality.

Grain and roughage should be fed separately to sheep. If sheep are fed in close quarters the hay should be supplied daily, since they dislike provender that has been "blown on," as shepherds say. In feeding sheep in open lots, as is done thruout the West, racks sufficiently large to hold roughage for several days are often used. Grain troughs should have a wide, flat bottom, forcing the sheep to consume the grain slowly. Fifteen inches of linear trough space should be provided for each animal.

837. Water.—Opinions as to the amount of water necessary for sheep vary more than with any other domestic animal. In countries with heavy dews and ample succulent feed in summer, and where roots are largely used in winter, water may possibly be denied sheep, but ordinarily it is a necessity. Because of the danger of infestation with internal parasites, drinking from stagnant pools must be avoided. On the arid ranges of the Southwest, when grazing on certain succulent plants, like singed cacti, sheep sometimes go 60 days without water.[27] The wise shepherd will under all usual conditions see that his sheep are supplied with water daily.

A sheep needs from 1 to 6 quarts of water daily, according to feed, temperature, and weather. Ewes suckling lambs, and sheep that are being fattened require more water than those being simply carried thru the winter. The following table presents data gathered at the Michigan[28] and Colorado[29] Stations on the amount of water consumed by fattening lambs, averaging about 80 lbs. at the beginning of the trials:

[24] Mich. Bul. 128.

[25] Mo. Bul. 115.

[26] Colo. Bul. 187.

[27] Wilcox and Smith, Farmers' Cyclopedia of Live Stock, p. 590.

[28] Mich. Buls. 113, 128, 136.

[29] Colo. Bul. 75.

Water drunk by lambs on various rations during fattening

Rations	Av. daily gain Lbs.	Water drunk daily Lbs.	Water drunk per 100 lbs. gain Lbs.	No. of trials
Michigan				
Grain and clover hay, open-yard feeding	0.22	1.4	599	1
Grain and clover hay................	0.28	2.8	979	8
Grain, roots, and clover hay...	0.36	1.9	540	3
Clover hay and sugar beets..........	0.13	0.3	314	1
Colorado				
Grain and alfalfa hay (cold water)	0.36	5.1	1,423	2
Grain and alfalfa hay (warm water) ...	0.36	5.3	1,514	2

Adding roots to the ration greatly decreased the water requirement, the lambs fed clover hay and unlimited sugar beets drinking only 0.3 lb. each daily. Lambs fed in an open yard required less water than those in confinement, due probably to the lower temperature outside. Supplying lambs fattening on alfalfa hay and grain with warm instead of cold water made no difference either in the quantity of water drunk or in the rate and economy of the gains produced.

Gray and Ridgeway of the Alabama Station[30] found that in late summer ewes in confinement drank 2.5 lbs. of water each while living on green sorghum forage, and 6.1 lbs. when on cottonseed meal and hulls. (103)

838. Salt.—Sheep require salt, which should be available at all times, for an irregular supply induces scouring. In winter it may be given in a trough used only for this purpose. In summer salt may be rendered doubly useful by scattering it on sprouts growing about stumps, on brush patches, or over noxious weeds. Some western sheep raisers never salt their sheep but allow them to eat alkali, which is safe when it contains 80 per ct. salt.[31] It is believed that salted sheep are less liable to become locoed.

In an experiment in France[32] in which 3 lots of sheep were fed the same ration of hay, straw, potatoes, and beans, those receiving a daily allowance of 0.5 oz. of salt with their feed gained 4.5 lbs. more per head than those fed no salt, and 1.25 lbs. more than those fed 0.75 oz. per head daily. This indicates that sheep may be given too much as well as too little salt. The fleeces of the salt-fed sheep were better and heavier than those fed no salt. (101)

839. Weight and gains of fattened wethers.—By far the most comprehensive data on the weights and gains of fattened wethers of different ages and from the various breeds are furnished by the records of the animals winning prizes at the Smithfield Club Show, London, England. Below are presented these data for the years 1895 to 1912, inclusive.[33] As given in these records the daily gain includes the weight of the animal at birth.

[30] Ala. Bul. 148.

[31] Wilcox and Smith, Farmer's Cyclopedia of Live Stock, p. 590.

[32] Abs. in Agr. Jour. and Min. Rec. 5 (1902), p. 361.

[33] Lond. Live Stock Jour., Vols. 42-76.

Weight of prize-winning wethers at Smithfield

Breed	Wether lambs				Yearling wethers			
	Number	Av. age	Av. wt.	Av. daily gain	Number	Av. age	Av. wt.	Av. daily gain
Middle-wool		Days	Lbs.	Lbs.		Days	Lbs.	Lbs.
Cheviot	35	238	141	0.59	53	592	224	0.37
Dorset	49	331	200	0.60	23	679	261	0.38
Hampshire	94	309	208	0.67	78	661	282	0.42
Mountain	36	232	132	0.56	60	591	197	0.33
Oxford	56	298	196	0.66	53	649	285	0.44
Shropshire	57	266	159	0.58	58	636	253	0.39
Southdown	99	286	150	0.52	105	637	202	0.31
Suffolk	76	287	201	0.70	56	648	291	0.44
Long-wool								
Cotswold	25	276	188	0.68	15	624	292	0.46
Devon	42	276	188	0.68	28	625	268	0.42
Kent	73	250	160	0.64	65	606	267	0.44
Leicester	54	247	157	0.64	59	607	273	0.45
Lincoln	48	290	209	0.72	55	639	334	0.52

The greater economy of the gains made by lambs is shown by the fact that the lambs made daily gains ranging from 0.52 lb. to 0.72 lb., while those of the yearlings were considerably lower, ranging from 0.31 to 0.52 lb. per head daily.

840. Weight of fattened sheep.—The weights of fat sheep of the several breeds competing for prizes at the American Fat-Stock Show, Chicago, during the years 1878 to 1884, inclusive,[34] were as follows:

Weights of fat sheep of various breeds—American Fat-Stock Show

Breed	Wethers			Ewes		
	Under 1 year	1 year and under 2 years	2 years or over	Under 1 year	1 year and under 2 years	2 years or over
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cotswold	142	199	258	127	235	273
Other long wools	151	239	263	112	204	238
Southdown	119	172	205	97	130	169
Other middle wools	117	181	223	87	208	211
American Merino	79	112	137	52	73	101
Grades or crosses	118	188	221	122	165	213

In most instances the ewes of a given breed and age were somewhat lighter in weight than the wethers.

841. Slaughter tests; dressing percentage.—The records of the slaughter competitions at the Smithfield Club Show[35] also furnish the most extensive data available on the dressing percentage, and weight of internal fat, pluck (heart, liver, and lungs), and skin for wethers of the different breeds. In the following table are averaged the results of these "block" tests for 20 years, 1895-1914 inclusive.

[34] Trans. Dept. Agr., Ill., 1884, p. 228.

[35] Lond. Live Stock Jour., Vols. 42-80.

Smithfield slaughter tests

Breed and age	Av. live wt. at slaughter	Av. wt. of dressed carcass	Av. per ct. of dressed carcass	Av. wt. of fat	Av. wt. of pluck	Av. wt. of skin	No. of animals
	Lbs.	Lbs.		Lbs.	Lbs.	Lbs.	
Blackfaced, lambs	116	71	61	6.6	3.7	14.6	7
Blackfaced, 1–2 years	171	110	64	9.0	4.4	18.6	16
Cheviot, lambs	113	67	59	5.8	3.6	12.6	54
Cheviot, 1–2 years	147	94	64	6.9	4.4	14.3	68
Hampshire, lambs	163	102	63	5.2	5.1	15.0	54
Hampshire, 1–2 years	209	135	65	6.8	6.0	15.8	30
Kent, lambs	141	85	60	5.2	5.0	19.4	5
Kent, 1–2 years	242	155	64	5.5	6.0	27.0	2
Shropshire, 1–2 years	259	175	68	6.2	7.0	25.2	4
Southdown, lambs	123	76	62	4.3	3.9	10.8	54
Southdown, 1–2 years	142	92	65	6.2	4.1	12.0	45
Suffolk, lambs	152	95	62	7.0	5.0	13.6	104
Suffolk, 1–2 years	188	121	64	10.6	5.7	14.3	43
Welsh, 1–2 years	121	74	61	8.8	3.4	11.0	14
Cross-bred, lambs	129	79	61	5.9	4.2	13.2	106
Cross-bred, 1–2 years	161	102	63	8.3	5.0	14.8	101

It will be noted that the yearlings yielded a slightly higher percentage of dressed carcass than the lambs. These wethers were thoroly finished, and thus their dressing percentage is higher than with sheep as usually fattened for the market. A survey of the experiments at the various stations in which slaughter tests have been conducted with the animals fattened shows that the usual dressing percentage of lambs or yearlings ranges from 48 to 57 per ct., depending on how completely the animals were fattened.

842. Shrinkage in shipping.—During 4 winters Linfield of the Montana Station[36] fattened average range lambs and 2-yr.-old wethers on clover hay and grain, shipping them from Bozeman to Chicago, a distance of about 1,440 miles. Lambs, averaging 87.5 lbs. when shipped, shrank 7.6 per ct. on the average, the range being 4.6 to 8.7 per ct. The 2-yr.-old wethers shrank somewhat less, averaging 6.8 per ct., with a range of 5.1 to 8.6 per ct. The older sheep yielded 2.2 per ct. more dressed carcass.

Shaw[37] states that fattened lambs weighing under 100 lbs., when 4 days in transit, will shrink 7 to 8 lbs.; 1-yr.-old wethers weighing about 120 lbs., approximately 10 lbs.; and aged wethers and ewes about 12 lbs. On shipping lambs fattened in 4 trials on corn and either clover hay, alfalfa hay, corn stover, soybean straw, or timothy hay, with and without the addition of a nitrogenous supplement, Carmichael and Hammond of the Ohio Station[38] found no variation in shrinkage attributable to the ration. Lambs shipped 135 to 149 miles shrank 1.3 to 6.8 per ct.

When sheep are marketed off pasture, especially rape, excessive shrinkage from scouring may be prevented by giving dry feed for a day or more prior to shipping. The grain ration should be decreased previous

[36] Mont. Buls. 47, 59.

[37] Management and Feeding of Sheep, p. 365.

[38] Ohio Buls. 187, 245.

to shipping for the same reason. Shaw[39] regards oats as the safest concentrate to feed sheep when in transit.

843. Wool production.—A general discussion of the nutrients required for wool production has been given in an earlier chapter. (**151-2**) Soil and climate produce marked effects on the characteristics of sheep, as shown by Brown[40] in his study of the evolution of the various English breeds. The rich lowlands of England with their abundant, nutritious grasses produced the heavy-bodied, plethoric Long-wools, the next higher lands with less abundant herbage furnished the Downs and Middle-wools, while the mountains with scanty herbage produced the active, still lighter breeds. Coleman[41] states that the peculiar luster of the Lincoln wool diminishes when these sheep pass to a less congenial soil, and that wool in certain districts of Yorkshire brings a higher price than that of other localities, due to the favorable influence of soil and climate. He further states that limestone soils, otherwise peculiarly suited to sheep, tend to harshness in wool which renders it less valuable than that from sheep living on clays or gravels.

To prevent injury to the wool, feeding racks should be so constructed that seeds and chaff will not lodge on the neck and shoulders of the sheep, and the feed lot or barn must be well bedded so that the wool will not become soiled.

Weiske and Dehmel[42] found that sheep shorn 6 times a year produced less unwashed wool, but nearly 25 per ct. more pure wool fiber than those shorn annually, but such short wool is of low value.

[39] Management and Feeding of Sheep, p. 361.
[40] British Sheep Farming.
[41] Cattle, Sheep, and Pigs of Great Britain.
[42] Fütterungslehre, 1872, p. 511.

CHAPTER XXXI

FEEDS FOR SHEEP

I. Concentrates for Sheep

In the following articles, which discuss the value of various feeding stuffs for sheep, especially for fattening animals, it will be noted that nearly all the trials reviewed were with lambs. This is due to the facts, already pointed out, that lambs make better use of their feed and that their flesh is in greater demand. (**831**) In all trials where the weight of the lambs and duration of the fattening period are not stated, it may be assumed that either western lambs weighing about 65 lbs. or eastern lambs of about 80 lbs. were used, and that the feeding period covered from 12 to 15 weeks.

844. Indian corn.—Corn, the best single grain for fattening sheep, is the cereal most commonly used over the United States as far west as Colorado, beyond which wheat and barley are more generally fed. Legume hay, rich in protein, admirably supplements this carbonaceous grain. Hence, the combination of corn and legume hay has become a standard ration for fattening sheep over a large extent of our country. In this chapter, so far as possible, other rations are compared with this successful combination. To show the possibilities of this ration, below are averaged the results from 8 stations with 26 lots, including 527 lambs, which were fed an unlimited allowance of shelled corn and either clover or alfalfa hay, for periods averaging 90 days. The results are also given from 4 stations at which 17 lots, including 1,180 lambs, were fed a limited allowance of shelled corn (from 0.7 to 1.1 lbs. per head daily), with the same roughages, in trials averaging 92 days.

Corn and legume hay for fattening lambs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Hay Lbs.
Corn allowance unlimited				
Shelled corn, 1.3 lbs.				
Clover or alfalfa hay, 1.4 lbs.........	67	0.32	400	436
Corn allowance limited				
Shelled corn, 0.9 lb.				
Clover or alfalfa hay, 2.1 lbs.........	60	0.32	288	655

The lambs given a full feed of corn consumed an average ration of 1.3 lbs. shelled corn and 1.4 lbs. clover or alfalfa hay and gained 0.32 lb. per head daily, requiring 400 lbs. shelled corn and 436 lbs. hay per 100 lbs. gain. Due probably to the superior quality of the hay fed, the lambs getting the limited corn allowance made as good gains as those on a full feed of corn. These lambs required 655 lbs. of hay and only 288 lbs. of corn for 100 lbs. of gain. From these averages, the feeder may readily calculate the cost and possible profits of fattening lambs under reasonably favorable conditions, and when the fattening period is not too extended. (**201-7**)

845. Corn requires supplement.—Owing to its carbonaceous character corn should be supplemented with some variety of legume hay, or if this is not available then with some protein-rich concentrate, even when fed to fattening sheep or lambs. (**201**)

This is shown in the following table, in the first division of which are summarized the results of 7 trials, averaging 81 days, in each of which corn was fed with clover or alfalfa hay to one lot of lambs and with timothy or prairie hay to another lot. In the second division are given the results of 4 trials, averaging 80 days, in which the effect of adding linseed or cottonseed meal to a ration of corn and timothy hay was studied. Thus, the first division shows the value of supplementing corn with legume hay, and the second, of adding a nitrogenous concentrate to a ration of corn and carbonaceous hay.

Corn requires supplement for fattening lambs

Average ration	Initial weight	Daily gain	Feed for 100 lbs. gain	
			Concentrates	Hay
	Lbs.	Lbs.	Lbs.	Lbs.
*Legume hay as supplement to corn**				
Unbalanced ration, 164 lambs				
Corn, 0.9 lb.				
Carbonaceous hay, 1.0 lb.	59	0.19	497	547
Balanced ration, 172 lambs				
Corn, 1.1 lbs.				
Legume hay, 1.5 lbs	59	0.32	340	475
Nitrogenous concentrate as supplement to corn†				
Unbalanced ration, 90 lambs				
Corn, 1.2 lbs.				
Timothy hay, 1.0 lb.	64	0.23	520	448
Balanced ration, 90 lambs				
Corn, 1.2 lbs.				
Cotton- or linseed meal, 0.2 lb.				
Timothy hay, 1.0 lb.	64	0.30	463	334

*Average of 1 trial by Burnett (Nebr. Bul. 66), 1 by Emery (Wyo. Bul. 51), 1 by Faville (Wyo. Bul. 85), 1 by Morton (Wyo. Bul. 73), and 3 by Skinner and King (Ind. Bul. 162).

†Average of 1 trial by Carmichael and Hammond (Ohio Bul. 245), 1 by Hays (Minn. Bul. 31), and 2 by Skinner and King (Ind. Bul. 162).

While the lambs fed corn with carbonaceous timothy or prairie hay gained only 0.19 lb. per head daily, those fed corn with legume hay, either clover or alfalfa, gained 0.32 lb. The lambs on the unbalanced ration required 46 per ct. more grain and 15 per ct. more hay than those on legume hay.

Supplementing the carbonaceous ration of corn and timothy hay with 0.2 lb. of protein-rich cotton or linseed meal per head daily, increased the gains and lowered the amount of feed required for 100 lbs. gain. Lambs will go off feed more readily when corn is fed without being properly supplemented by some protein-rich feed. On the other hand, in these trials the lambs fed corn and legume hay or corn, carbonaceous hay, and a nitrogenous supplement had good appetites at all times.

846. Corn alone and in combination.—Altho corn and legume hay alone have given excellent results in numerous experiments and in extensive commercial feeding, many maintain that the animals have better appetites and are less subject to digestive disorders when a variety of grains is used, especially toward the close of the fattening period, or when lambs are being forced on heavy grain allowances. Without question, mixing a more bulky concentrate, such as oats or wheat bran, with corn is advisable to prevent digestive trouble in starting animals on feed. Whether there is any benefit in adding other feeds to corn for the sake of variety when the lambs are on full feed seems to be an unsettled question, for in trials reviewed later (**851**), the Indiana Station secured just as good results with corn as the sole concentrate, when fed with clover hay and corn silage, as with a combination of corn and oats. Much of the trouble experienced in feeding corn as the sole concentrate is due to its improper use with carbonaceous roughage without any nitrogenous supplement.

At the Wisconsin Station Craig[1] fed lambs grazing on bluegrass pasture corn meal alone, corn meal and oats, or corn meal and peas for 8 weeks before weaning and for the same period after weaning. The lambs fed corn meal alone made the largest and most economical gains before weaning, and as large and economical gains as the other lots after weaning. In this case, the needed protein came from the dam's milk and the pasture grass.

847. Feeding corn in various forms.—To determine the relative efficiency of different methods of preparing corn for fattening lambs, Evvard[2] at the Iowa Station fed 6 lots, of 40 range lambs each, averaging 52 lbs., corn in various forms, as shown in the table, all lots getting 0.6 lb. alfalfa hay, 0.7 lb. corn silage, and 0.15 lb. linseed meal per head daily in addition.

Various methods of preparing corn for fattening lambs

Average daily corn allowance	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Hay Lbs.	Silage Lbs.	Cost of 100 lbs. gain* Dollars
Lot I, Whole ear corn, 1.3 lbs.	0.33	438	181	225	5.95
Lot II, Broken ear corn, 1.3 lbs.	0.33	425	177	220	5.86
Lot III, Shelled corn, 1.3 lbs.	0.34	416	175	217	5.81
Lot IV, Ground corn, 1.2 lbs.	0.33	425	184	228	6.18
Lot V, Whole, broken and ground corn, 1.3 lbs.	0.35	399	167	208	5.51
Lot VI, Corn-and-cob meal, 1.2 lbs.	0.34	415	172	214	5.77

*Corn, per bushel, on basis of 56 lbs. grain—whole ear 54 cts., broken ear 55 cts., shelled 56 cts., ground 59 cts., and corn-and-cob meal 60 cts.; oil meal, $30; silage, $3.50; and alfalfa hay $12 per ton.

[1]Wis. Rpt. 1897.

[2]Information to the authors.

In the table the equivalent amount of shelled corn is given for each lot; e. g., each lamb in Lot I received daily ear corn equivalent to 1.3 lbs. of shelled corn. The whole ear corn, fed Lot I, made practically as large and economical gains as broken ear corn or shelled corn, tho shelling the corn decreased the feed required for 100 lbs. gain enough to slightly more than pay the expense. Wing[3] declares that no ration will make better or more marketable lambs than a combination of ear corn, corn silage, and alfalfa hay. Lot IV, fed ground corn, made the lowest gains in the trial. From previous trials Evvard concluded that the best results may be secured by starting the lambs on ear corn, changing to broken ear corn as the feeding period progresses, and finishing on ground corn and broken ear corn; i. e., increasing the preparation of the grain fed as the lambs fatten. Lot V, fed in this manner, made slightly the largest and most economical gains. Corn-and-cob meal ranked second in amount of gains and economy of production. To study the most economical method of preparing corn for lambs fed clover hay Coffey fed 5 lots, each of 16 western lambs averaging 65 lbs. in weight, clover hay and corn in various forms for 98 days in a trial at the Illinois Station[4] with the results shown in the table:

Methods of preparing corn for fattening lambs

Average ration	Daily gain	Feed for 100 lbs. gain Corn	Roughage
	Lbs.	Lbs.	Lbs.
Lot I, Ear corn, 1.6 lbs. Clover hay, 1.3 lbs.......	0.293	439*	453
Lot II, Shelled corn, 1.3 lbs. Clover hay, 1.3 lbs....	0.295	432	449
Lot III, Ground corn, 1.3 lbs. Clover hay, 1.3 lbs...	0.264	483	505
Lot IV, Corn-and-cob meal, 1.5 lbs. C. hay, 1.2 lbs.	0.264	489*	475
Lot V, Shelled corn, 0.06 lb. Clover hay, 1.0 lb. Shock corn, 2.7 lbs....	0.247	23	406 / 1,111†

*Reduced to shelled corn basis.
†Shock corn, containing 53 per ct. of ears.

The lambs in Lot II, fed shelled corn, made the largest and most economical gains. Both ground corn and corn-and-cob meal produced smaller and more expensive gains than did shelled corn. Ear corn, fed Lot I, produced about as large and economical gains as shelled corn. Lot V was fed a small amount of shelled corn until they had learned to husk shock corn, and thereafter were given corn only in the form of shock corn. These lambs made somewhat lower gains than the other lots, and, including the corn in the shock corn, required 522 lbs. of corn for 100 lbs. gain. Coffey points out that both ear corn and shock corn are better suited for feeding on a thick sod than in a dry lot or barn, for they may be scattered on the sod so that each lamb will have an equal chance to feed and little will be wasted. In the lot or barn lambs are apt to drop the ears on the ground where they become soiled or bunch them up in the trough so that each lamb does not get its share.

From these trials we may conclude that it will rarely pay to grind corn for fattening lambs, except perhaps where they are fairly fat and

[3] Sheep Farming in America, p. 285. [4] Information to the authors.

it is desired to continue feeding them for some time. (**423, 835**) When ground corn is to be fed, it should be cracked or ground coarsely, for Carlyle[5] found in repeated trials that lambs ate corn ground coarsely much more readily than that which was fine and powdery.

848. Barley.—Thruout the western range district, where but little corn is grown, barley is extensively used for fattening sheep and lambs. In the following table are summarized the results of 6 trials, averaging 96 days, in which brewing or Scotch barley was compared with shelled corn for fattening lambs when fed with alfalfa hay. The table also summarizes 4 trials, averaging 98 days, in which barley was compared with shelled corn when fed with carbonaceous roughage—prairie, timothy, or mixed prairie and brome hay.

Barley vs. corn for fattening lambs

Average ration	Initial weight	Daily gain	Feed for 100 lbs. gain	
			Grain	Hay
	Lbs.	Lbs.	Lbs.	Lbs.
*With alfalfa hay**				
Lot I, total of 355 lambs				
Whole barley, 0.9 lb.				
Alfalfa hay, 2.4 lbs.	62	0.31	296	777
Lot II, total of 355 lambs				
Shelled corn, 0.9 lb.				
Alfalfa hay, 2.3 lbs.	60	0.32	283	708
With carbonaceous hay†				
Lot I, total of 57 lambs				
Whole barley, 1.2 lbs.				
Hay, 1.3 lbs.	71	0.21	580	598
Lot II, total of 57 lambs				
Shelled corn, 1.2 lbs.				
Hay, 1.3 lbs.	71	0.23	528	586

*Average of 3 trials by Faville (Wyo. Buls. 81, 85, 103), 1 by Buffum and Griffin (Colo. Bul .75), and 2 by Morton (Colo. Bul. 187).

†Average of 1 trial each by Hays (Minn. Bul. 31), Morton (Wyo. Bul. 73), Faville (Wyo. Bul. 89), and Wilson and H. G. Skinner (S. D. Bul. 86).

With alfalfa hay for roughage, the lambs fed whole barley made only slightly smaller gains than those fed corn, the former consuming 5 per ct. more grain and 10 per ct. more hay for 100 lbs. gain. In trials by Morton with 450 lambs, Scotch barley proved fully equal to shelled corn in the amount and economy of gains. With carbonaceous hay, the barley-fed lambs required 10 per ct. more grain and only 2 per ct. more hay for 100 lbs. gain than those fed corn. These trials show that good brewing or Scotch barley nearly equals corn for fattening lambs. California feed barley was found by Morton to have slightly lower value than the heavier Scotch barley, lambs given feed barley requiring 11 per ct. more grain and 4 per ct. more alfalfa hay than those fed Scotch barley. Altho somewhat richer in protein than corn, barley is decidedly a carbonaceous grain and hence gives the best results when fed with legume hay, as the

[5]Wis. Rpt. 1899, p. 45.

table shows. When fed with carbonaceous hay, the ration should be supplemented with a protein-rich concentrate, such as linseed or cottonseed meal. (**226**)

At the Wyoming Station Faville[6] found that soaking, cracking, or grinding western Scotch barley, which is harder than eastern brewing barley, did not increase its value for lambs. It will probably pay to roll or crack the hard bald or hulless barley, as Faville[7] found that lambs passed more of it undigested than of Scotch barley. Cooke[8] at the Colorado Station found that, when ground, bald barley formed a sticky mass in the lambs' mouths and they would not consume more than 1 lb. per head daily. (**835**)

849. Wheat.—Rarely will wheat be fed to sheep unless off grade or low in price. To show its value compared with shelled corn, the following table presents the results of 3 trials, averaging 104 days, in which good quality common wheat was compared with corn in lamb-feeding trials. In the table are also summarized the results of 3 trials, averaging 101 days, in which wheat and barley were compared.

Wheat vs. corn or barley for fattening lambs

Average ration	Initial weight	Daily gain	Feed for 100 lbs. gain	
			Grain	Hay
	Lbs.	Lbs.	Lbs.	Lbs.
*Wheat vs. corn**				
Lot I, total of 29 lambs				
Wheat, 1.4 lbs.				
Hay, 1.5 lbs.	78	0.30	524	482
Lot II, total of 29 lambs				
Shelled corn, 1.4 lbs.				
Hay, 1.5 lbs.	79	0.30	515	472
Wheat vs. barley†				
Lot I, total of 56 lambs				
Wheat, 1.0 lb.				
Hay, 1.7 lbs.	66	0.25	382	686
Lot II, total of 56 lambs				
Barley, 1.0 lb.				
Hay, 1.8 lbs.	69	0.25	400	712

*Average of 2 trials by Wilson and H. G. Skinner (S. D. Buls. 80, 86) and 1 by F. B. Mumford (Mich. Bul. 128).
†Average of 2 trials by Linfield (Mont. Buls. 47, 59) and 1 by Wilson and H. G. Skinner (S. D. Bul. 86).

The lambs fed wheat made the same gains as those fed corn, and required only 2 per ct. more grain and hay for 100 lbs. gain. Those fed wheat and barley also made the same average daily gains, but the barley-fed lots required 5 per ct. more grain and 3 per ct. more hay for 100 lbs. gain. Carlyle and Iddings[9] likewise found wheat slightly superior to barley in a trial with 505 lambs at the Idaho Station in which 0.8 lb. of either wheat or barley was fed with a basal ration of 0.3 lb. oats and 2.4 lbs. alfalfa hay. These experiments, confirmed by British tri-

[6] Wyo. Bul. 103. [7] Wyo. Bul. 89. [8] Colo. Bul. 40. [9] Idaho Bul. 77.

als,[10] show that good quality wheat is slightly superior to barley and nearly equal to corn for fattening sheep. Since wheat is a carbonaceous grain, the best results are secured when it is fed with legume hay.

In 2 trials at the South Dakota Station Wilson and Skinner[11] found durum, or macaroni, wheat practically equal to common wheat for fattening lambs. Frosted wheat, in a trial by Foster and Merrill[12] at the Utah Station, produced as large and more economical gains than marketable wheat. (**215**)

850. Wheat screenings.—The value of wheat screenings from the elevators and mills depends on their quality, the light, chaffy grades being more like a roughage than a concentrate. Successful feeders wisely utilize screenings of low grade in getting the lambs on feed, and as fattening advances change to the heavier screenings. Hundreds of thousands of Montana sheep and lambs were annually fed during the nineties on wheat screenings in feed lots near St. Paul, Minnesota. The screenings were fed in sheds and usually from self feeders, as the bits of chaff and straw in the feed render it so bulky that there is less danger of foundering than when corn is fed in self feeders. With the bulky class of screenings which were used, little or no hay was required. During the season of 1902 about 330,000 sheep and lambs were fattened in these feed lots.[13] Two years later the number fell below 200,000, and at the present time, because of prohibitory prices for screenings and their poor quality, this district has ceased to be a factor of importance in the winter mutton supply. Screenings are still employed more or less extensively in other sections of the country for sheep feeding. (**222**)

The relative value of heavy wheat screenings and good wheat for fattening lambs is shown in the following table summarizing 3 trials, from 90 to 97 days in length, where either clover or alfalfa hay was fed for roughage to lambs averaging 58 lbs. in weight.

Wheat screenings vs. good-quality wheat for lambs

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Grain Lbs.	Hay Lbs.
*Lot I, 68 lambs**			
Wheat screenings, 0.8 lb. Legume hay, 1.8 lbs......	0.26	307	695
*Lot II, 70 lambs**			
Wheat, 0.8 lb. Legume hay, 1.7 lbs................	0.22	347	744

*Average of 2 trials by Linfield (Mont. Buls. 47, 59) and 1 by Foster and Merrill (Utah Bul. 78).

The table shows that when fed with legume hay heavy-weight screenings produced larger and more economical gains than good wheat. Foster and Merrill found that it required 35 per ct. more light-weight, chaffy screenings than those of heavy weight for 100 lbs. of gain. Screenings should be fed close to the mills or elevators, thereby avoiding large

[10] Trans. Highl. and Agr. Soc. Scotland, 1910.
[11] S. D. Bul. 86. [12] Utah Bul. 78.
[13] Breeder's Gazette, 46, 1904, p. 1000.

freight bills. As with wheat, the best returns come thru feeding in combination with legume hay.

Lambs fed by Hays[14] at the Minnesota Station on unground screenings containing 90 per ct. of either small wheat, wild buckwheat, or pigeon-grass seed, made as large gains as others receiving cracked corn, but required 42 per ct. more grain per 100 lbs. gain, in the case of those fed small wheat, and 67 per ct. more with those fed pigeon-grass seed. To prevent the spread of weeds, screenings should be ground.

851. Oats.—This grain, so well liked by sheep, is especially useful and safe in getting them on feed and is excellent for the breeding flock. (**883**) Owing to their usual high price and the fact that they induce growth rather than fattening, oats are rarely economical as the sole grain for fattening sheep. When used, the proportion of oats to other concentrates should be decreased as the fattening period progresses. At the South Dakota Station Wilson and H. G. Skinner[15] compared the value of oats and shelled corn as the sole grain for lambs fed mixed prairie and brome hay for roughage in trials averaging 111 days, with the results shown in the following table. In the second division of the table are given the results secured by J. H. Skinner and King[16] at the Indiana Station in three 90-day trials, in which a mixture of oats and corn was compared with shelled corn alone, clover hay and corn silage forming the roughage.

Value of oats for fattening lambs

Average ration	Initial weight	Daily gain	Feed for 100 lbs. gain		
			Grain	Hay	Silage
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Oats vs. corn					
Lot I, 10 lambs					
Oats, 1.6 lbs.					
Mixed hay, 1.3 lbs.	70	0.25	650	535	...
Lot II, 10 lambs					
Shelled corn, 1.5 lbs.					
Mixed hay, 1.3 lbs.	71	0.28	561	485	...
Oats and corn vs. corn					
Lot I, total of 75 lambs					
Oats, 0.5 lb.					
Corn, 0.7 lb.					
Clover hay, 1.0 lb.					
Corn silage, 1.4 lbs.	60	0.32	365	329	453
Lot II, total of 75 lambs					
Corn, 1.2 lbs.					
Clover hay, 1.1 lbs.					
Corn silage, 1.4 lbs.	60	0.33	349	323	428

Both in the South Dakota trial where oats was fed as the sole grain and in the Indiana trials where a mixture of oats and shelled corn was used, the lambs getting either oats or oats and corn, required more feed

[14]Minn. Bul. 31. [15]S. D. Bul. 86.

[16]Ind. Buls. 168, 179; information to the authors.

for 100 lbs. gain than those fed corn only. The Indiana trials show that in a ration properly balanced with legume roughage corn alone is as satisfactory for fattening lambs as a mixture of corn and oats.

In the South Dakota trial the lambs fed corn made larger and more economical gains than those fed oats. In the Indiana trials the lambs fed corn as the sole grain made slightly larger gains than those fed a mixture of oats and corn, and required less feed per 100 lbs. gain. In starting Lot II on feed, some oats was mixed with the corn during the first few days. These trials indicate that when lambs are on full feed, corn as the sole grain is as satisfactory as a mixture of corn and oats, when fed with legume hay. (**846**)

In 2 trials at the Montana Station by Linfield[17] lambs fed clover hay for roughage made nearly as large gains on oats as those fed barley, but required 6 per ct. more grain and 5 per ct. more hay for 100 lbs. gain. (**223**)

852. Emmer.—Owing to greatly increased production, emmer (wrongly called spelt) has become an important concentrate for sheep and lambs in the northern plains states. The value of emmer compared with shelled corn is shown in the following table, in which the results are summarized for 3 trials, averaging 91 days, where alfalfa hay was fed, and 2 trials, averaging 110 days, in which the roughage was prairie and brome hay:

Emmer vs. corn for fattening lambs

Average ration	Initial weight	Daily gain	Feed for 100 lbs. gain	
			Grain	Hay
	Lbs.	Lbs.	Lbs.	Lbs.
*With alfalfa hay, 3 trials**				
Lot I, total of 81 lambs				
Emmer, 0.9 lb.				
Alfalfa hay, 2.4 lbs.	59	0.28	324	875
Lot II, total of 81 lambs				
Shelled corn, 0.9 lb.				
Alfalfa hay, 2.2 lbs.	59	0.31	276	673
With mixed hay, 2 trials†				
Lot I, total of 18 lambs				
Emmer, 1.8 lbs.				
Mixed hay, 1.4 lbs.	75	0.29	660	511
Lot II, total of 19 lambs				
Shelled corn, 1.6 lbs.				
Mixed hay, 1.4 lbs.	76	0.32	513	462

*Average of 2 trials by Faville (Wyo. Buls. 81, 85) and 1 by Buffum and Griffin (Colo. Bul. 75).
†Average of 2 trials by Wilson and H. G. Skinner (S. D. Buls. 80, 86).

Both with alfalfa and with prairie and brome hay as the roughage, emmer produced 0.03 lb. less daily gain per lamb, altho the lambs fed emmer ate as much or more grain. With alfalfa hay, the corn-fed lambs required only 85 per ct. as much grain and 77 per ct. as much hay for 100 lbs. gain as those fed emmer. With prairie and brome hay, 78 per

[17] Mont. Buls. 47, 59.

ct. as much grain and 90 per ct. as much hay was required by the corn-fed lambs as by those receiving emmer. Considering the larger amount of both grain and hay required per 100 lbs. gain by the lambs fed emmer, we may conclude the value of emmer to be about 75 per ct. that of shelled corn. In the South Dakota trials emmer had a somewhat higher value when fed with barley or corn, than when used as the sole concentrate. (233)

853. Kafir; milo.—Cochel of the Kansas Station[18] compared kafir and shelled corn in a 60-day trial with 3 lots, each of fifty 56-lb. lambs, fed 1.4 lbs. alfalfa hay and 1.1 lbs. sweet-sorghum silage per head daily for roughage.

Kafir vs. corn for fattening lambs

Average concentrate allowance		Daily gain Lbs.	Feed for 100 lbs. gain Grain Lbs.	Hay Lbs.	Silage Lbs.
Whole kafir, 0.9 lb.	Cottonseed meal, 0.19 lb.	0.35	308	385	309
Ground kafir, 0.9 lb.	Cottonseed meal, 0.19 lb.	0.36	303	378	303
Shelled corn, 0.9 lb.	Cottonseed meal, 0.19 lb.	0.40	269	335	271

In this, as in 2 previous trials at the same Station,[19] lambs fed kafir made satisfactory, tho slightly smaller gains than those fed corn. The lambs fed kafir in this test required about 15 per ct. more feed for 100 lbs. gain than those receiving corn. Grinding kafir did not increase its value for sheep. This trial is valuable and important in showing the excellent returns possible from feeds so well adapted to the southern plains states—sorghum silage, alfalfa hay, kafir, and cottonseed meal. Tho the stations have reported no tests with milo for fattening sheep, it should have substantially the same value as kafir. (236-40)

854. Miscellaneous carbonaceous concentrates.—*Dried beet pulp* produced as large and as economical gains as corn in a trial by Shaw at the Michigan Station[20] in which mixtures of either 4 parts dried beet pulp or 4 of corn, together with 2 parts wheat bran and 1 part linseed meal, were fed with clover hay to western lambs. Humphrey and Kleinheinz of the Wisconsin Station[21] found dried beet pulp equal to corn for producing growth in ewe lambs when oats were fed with both. (275)

Molasses-beet pulp showed no marked superiority over ordinary dried beet pulp in the trial by Shaw when 3 parts of either was fed with 1 part of linseed meal, clover hay forming the roughage. (277)

Beet molasses is now in some instances being fed to sheep in the vicinity of beet sugar factories in the West. Morton of the Colorado Station[22] states that it is used chiefly with the cheaper grades of sheep, such as old ewes. To avoid "smearing" the wool, the molasses is preferably mixed thoroly with cut hay or straw. In some cases no other concentrate is fed, and in others wet beet pulp and a little cottonseed cake are added to the ration. (276)

[18] Information to the authors.
[19] Breeder's Gaz., 51, 1907, p. 960.
[20] Mich. Bul. 220.
[21] Wis. Rpt. 1906.
[22] Information to the authors.

Millet seed, coarsely ground, was found by Wilson and H. G. Skinner[23] practically equal to corn for fattening lambs when fed with mixed prairie and brome hay. Sheep fed whole millet voided a large percentage of the seed undigested. (**243**)

855. Linseed and cottonseed meal or cake.—The value of these nitrogenous concentrates, the supplements most commonly used with sheep in balancing rations deficient in protein, has already been pointed out. (**845**) The relative value of linseed and cottonseed meal is shown in 2 trials presented in the following table, the first by Carmichael at the Ohio Station[24] and the second by Mumford, Trowbridge, and Hackedorn at the Missouri Station.[25]

Linseed vs. cottonseed meal for fattening sheep

Average ration	Initial weight	Daily gain	Feed for 100 lbs. gain	
			Concentrates	Hay
	Lbs.	Lbs.	Lbs.	Lbs.
Ohio Station, 112-day trial				
Lot I, 40 lambs				
Linseed meal, 0.2 lb.				
Shelled corn, 1.0 lb.				
Clover or alfalfa hay, 1.5 lbs.	65	0.30	397	497
Lot II, 40 lambs				
Cottonseed meal, 0.2 lb.				
Shelled corn, 1.0 lb.				
Clover or alfalfa hay, 1.5 lbs.	67	0.31	388	486
Missouri Station, 98-day trial				
Lot I, 20 yearling wethers				
Linseed meal, 0.2 lb.				
Shelled corn, 1.1 lbs.				
Clover hay, 1.8 lbs.	79	0.25	491	703
Lot II, 20 yearling wethers				
Cottonseed meal, 0.2 lb.				
Shelled corn, 1.1 lbs.				
Clover hay, 1.8 lbs.	78	0.24	511	748

These trials show that cotton- and linseed meal have substantially the same value for balancing the rations of fattening sheep and lambs. (**250, 254**)

Undecorticated cottonseed cake, which is similar to the cold-pressed cake sold in this country (**248**), was found by Bruce[26] at the Edinburgh Agricultural College to produce 0.06 lb. less gain per head daily with yearling wethers than linseed cake, when both were fed as the sole concentrate with hay and turnips. Wethers fed undecorticated cottonseed cake required 20 per ct. more cake and 29 per ct. more roots than those fed linseed cake. Lambs should not receive more than half a pound of linseed or cottonseed meal per head daily, and one-eighth or one-fourth pound, in combination with other concentrates, will usually pro-

[23] S. D. Bul. 86.
[24] Ohio Bul. 179.
[25] Mo. Bul. 115.
[26] Edinburgh and East of Scot. Col. Agr., Bul. 10.

vide a well-balanced ration. Linseed cake of pea size is better relished by sheep than the finely ground meal. (883)

856. Minor protein-rich concentrates.—*Field peas* and *soybeans* are usually too expensive to form the entire concentrate allowance for fattening lambs, but may be used with corn or other grains. Of several concentrate mixtures tested for fitting yearling wethers for show, the best results were secured with a mixture of peas, oats, and bran. Humphrey and Kleinheinz of the Wisconsin Station[27] show that peas produce firm flesh and, combined with other grains, are especially helpful in securing high quality mutton. (261, 860, 883)

Richards and Kleinheinz[28] fed one lot of 10 ewe lambs equal parts of soybeans and shelled corn and another equal parts of oats and corn, all receiving a daily roughage allowance of 0.8 lb. hay and 0.6 lb. corn stover per head. The results of the trial, which lasted 84 days, are shown below:

Soybeans vs. oats for ewe lambs

Average grain allowance	Daily gain Lbs.	Feed for 100 lbs. gain Grain Lbs.	Feed for 100 lbs. gain Roughage Lbs.
Lot I, Soybeans and corn, 1.2 lbs.	0.19	611	711
Lot II, Oats and corn, 1.2 lbs.	0.16	728	862

With these lambs, lightly fed, since they were intended for the breeding flock, soybeans and corn produced larger and more economical gains than oats and corn. (256)

Wheat bran should form no large part of the concentrate allowance for fattening sheep, for, like oats, it induces growth rather than fattening and is too bulky. When lambs are being started on feed, bran is useful for mixing with corn and other heavy concentrates to forestall digestive troubles. Bran is a most valuable feed for breeding ewes. (218, 883)

Dried distillers' and brewers' grains, rarely fed to sheep in this country, have given good results in Europe.[29] Aitken[30] of Scotland found that dried distillers' grains fed with roots, or with roots and hay, to fattening sheep produced as large gains as linseed meal. (282, 228)

Gluten feed, tho not relished by sheep, in a trial by Gilchrist[31] at Durham College, England, produced larger gains than split peas or equal parts of barley meal and undecorticated cottonseed meal, when fed as the sole concentrate with hay and rutabagas. (210)

Flesh meal, according to Schenke,[32] was readily consumed by sheep when it was fed with better-liked feed and formed not more than 5 to

[27] Wis. Rpt. 1905 and Bul. 232.

[28] Wis. Rpt. 1904.

[29] Pott, Handb. Ernähr. u. Futter., III, 1909, p. 241.

[30] Trans. Highl. and Agr. Soc. Scotland, 1900, 1901.

[31] Trans. Highl. and Agr. Soc. Scotland, 1910, p. 253.

[32] Landw. vers. Stat., 58, 1903, pp. 26, 27.

10 per ct. of the ration. Flesh meal produced larger but less economical gains than grain alone, and evidently increased the wool production.

Dried blood, fed to young lambs in place of milk, at the rate of about 0.5 lb. daily for each 100 lbs. live weight, gave excellent results in a trial by Regnard.[33] (271)

Tankage was found by Morrison and Kleinheinz[34] at the Wisconsin Station to be readily eaten by lambs when mixed with 9 parts coarsely ground corn. When fed with corn and poor-quality, over-ripe bluegrass hay, both feeds low in protein, 10 per ct. tankage was as effective as 18 per ct. linseed meal in balancing the ration. (270)

II. Roughages for Sheep

857. Legume hay.—The legumes are the prime source of roughage for sheep—in the East clover and alfalfa, thruout the West alfalfa with clover and field peas in certain sections, and in the South the cowpea, beggarweed, and other plants. It is more important for sheep than for cattle that the hay be fine-stemmed and leafy.

The superiority of legume over carbonaceous hay for sheep is shown in the following summary of 5 trials, averaging 99 days, in which rations of clover or alfalfa hay with corn as the sole concentrate, have been compared with rations of timothy or prairie hay with corn and cotton- or linseed meal, which were equally well balanced so far as the amount of protein was concerned:

Legume hay vs. carbonaceous hay for fattening lambs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Hay Lbs.
*Legume hay, 71 lambs**				
Clover or alfalfa hay, 1.5 lbs.				
Corn, 1.3 lbs.	63	0.32	388	455
*Carbonaceous hay, 63 lambs**				
Timothy or prairie hay, 1.0 lb.				
Corn, 1.0 lb.				
Cotton- or linseed meal, 0.2 lb.	63	0.24	505	422

*Average of 1 trial by Burnett (Nebr. Bul. 66), 1 by McDonald and Malone (Okla. Bul. 78), 1 by Morton (Colo. Bul. 73), and 2 by Skinner and King (Ind. Bul. 162).

Tho the lambs fed timothy or prairie hay received a well-balanced ration, those on clover or alfalfa made much larger gains and required less feed per 100 lbs. gain. So long as there is an ample supply of good legume hay of any kind, sheep show little desire for other roughage. (Chapter XIV)

858. Nitrogenous supplement with corn and legume hay.—The advantage of adding a nitrogenous concentrate to a ration of corn and legume hay for fattening lambs has been studied by several stations. The following table summarizes 10 trials in which a ration of clover or alfalfa hay with corn alone was compared with the legume hay and corn plus cotton- or linseed meal.

[33] Pott, Handb. Ernähr. u. Futter., III, 1909, p. 515. [34] Unpublished data.

Adding a supplement to a ration of corn and legume hay

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Hay Lbs.
*Lot I, 193 lambs**				
Corn, 1.3 lbs.				
Legume hay, 1.4 lbs.	63	0.32	402	424
*Lot II, 193 lambs**				
Corn, 1.1 lbs.				
Cotton- or linseed meal, 0.2 lb.				
Legume hay, 1.4 lbs.	63	0.33	402	428

*Average of 5 trials by Carmichael and Hammond (Ohio Buls. 187, 245), 1 by Coffey (Ill. Station, information to the authors), 1 by F. B. Mumford (Mich. Bul. 113), and 3 by Skinner and King (Ind. Buls. 162, 168).

In 7 of the trials the lambs fed the nitrogenous supplement made slightly larger gains and in 3, smaller gains than those on corn and legume hay alone. On the average, replacing 0.2 lb. of corn in the ration by the same weight of cotton- or linseed meal increased the daily gain 0.01 lb. but did not decrease the amount of concentrates or hay consumed for 100 lbs. gain. With normal prices for corn and nitrogenous concentrates, the only advantage from adding a nitrogenous supplement to an already well-balanced ration of corn and legume hay is evidently the fact that the gains are usually somewhat more rapid, enabling the feeder to put the lambs in condition for the market in a shorter time.

859. Legume hays compared.—*Red clover,* one of the best roughages for sheep, should be cut early to secure the leaves and heads, which are the portions most desired. (**347**) The relative values of *alfalfa* and *clover hay* for sheep is a disputed point. In trials covering 3 years at the Ohio Station,[35] Carmichael and Hammond found that lambs fed good quality alfalfa hay and shelled corn gained 0.02 lb. more per day on the average than those fed clover hay of the same quality, tho consuming 16 lbs. less grain and 9 lbs. less hay per 100 lbs. gain. Humphrey and Kleinheinz, when fitting yearling wethers for exhibition during 3 years at the Wisconsin Station,[36] found that clover hay produced slightly larger and more economical gains, but the carcasses from the alfalfa-fed wethers were superior. Skinner and King[37] in a 90-day test found good clover slightly superior to good alfalfa hay for fattening lambs when fed with shelled corn. From these data we may conclude that there is no material difference in the value of clover and alfalfa hays for sheep. (**338**) R. S. Shaw found *alsike clover hay* slightly superior to alfalfa or red clover in a trial at the Montana Station[38] where lambs were fed grain, hay, and roots. (**350**) *Cowpea hay* proved equal to alfalfa hay in a trial by McDonald and Malone at the Oklahoma Station,[39] while at the Kansas Station lambs fed cowpea hay by Cochel[40] required 14 per

[35] Ohio Bul. 245.
[36] Information to the authors.
[37] Ind. Bul. 179.
[38] Mont. Bul. 21.
[39] Okla. Bul. 78.
[40] Information to the authors.

ct. more grain and silage and 29 per ct. more hay for 100 lbs. gain than others fed alfalfa hay. (**357**) In a trial at the South Dakota Station[41] Wilson found *sweet clover hay* a palatable and satisfactory roughage, tho somewhat inferior to alfalfa. Lambs fed equal parts of shelled corn and oats with sweet clover hay, gained 0.43 lb. per head daily during a 67-day trial, requiring 442 lbs. grain and 319 lbs. hay for 100 lbs. gain. (**352**) In the same trial *field pea hay,* while relished by the lambs, produced lower gains than either alfalfa or sweet clover hay. (**355**)

Field bean straw proved a good substitute for clover hay in a trial by H. W. Mumford at the Michigan Station,[42] lambs fed a ration of 1.5 lbs. bean straw, 1.4 lbs. shelled corn and 1.2 lbs. rutabagas gaining 0.30 lb. daily, in comparison with 0.33 lb. for lambs fed clover hay. With bean straw, 9 per ct. more grain and 35 per ct. more dry fodder was required per 100 lbs. gain than with clover hay. Lambs fed a ration of 1.2 lbs. *soybean straw,* 1.2 lbs. shelled corn and 0.2 lb. linseed meal by Carmichael and Hammond at the Ohio Station[43] made daily gains of 0.28 lb. per head and required 499 lbs. concentrates and 420 lbs. soybean straw per 100 lbs. gain—a fair gain, tho 19 per ct. less than was made by lambs fed corn with alfalfa or clover hay. (**329**)

860. Field peas.—The fattening of lambs by grazing on field peas is an important industry in certain sections of the West, especially in the San Luis valley, Colorado.[44] Mexican peas, similar to the common Canadian field peas, are sown at the rate of 30 to 50 lbs. per acre, with a small quantity of oats or barley to support the vines and furnish additional feed. About November 1, as soon as most of the peas have matured, lambs or sheep are turned into the field, and without other feed are fattened in from 70 to 120 days. An acre of such peas will fatten from 8 to 15 lambs, each making a gain of from 6 to 8 lbs. per month. One acre of peas produces about $15 worth of lamb mutton at no expense for harvesting the crop. Confining the lambs to small areas by hurdles gives better results than allowing them to roam over the entire field. Sometimes the peas are cut, stacked, and fed to the lambs in yards. (**355**)

At the Wyoming Station[45] lambs grazed on field peas made larger gains and reached market in better condition than others fed alfalfa and corn. In a second trial Morton[46] found that altho the gains of alfalfa and corn fed lambs were 50 per ct. greater than those grazed on field peas, due to the low cost of producing the peas the net returns were the same. In this trial the lambs consumed 0.6 acre of peas for each 100 lbs. gain.

861. Timothy and other carbonaceous hay.—*Timothy hay* is unsatisfactory for sheep, being both unpalatable and constipating. The dry heads of this grass work into the wool, irritating the skin, lowering the quality of the wool and making shearing difficult. As has been shown

[41] S. D. Bul. 143. [43] Ohio Bul. 245. [45] Wyo. Bul. 64.
[42] Mich. Bul. 136. [44] Breeder's Gaz., 49, 1906, p. 244. [46] Wyo. Bul. 73.

before (**857**), even when a nitrogenous supplement is added to timothy hay and corn, the ration is still inferior to one of legume hay and corn. *Marsh hay* is too coarse and woody for sheep. *Bluegrass hay* and bright *oat straw* are preferable to either of these hays. (**311, 328**) *Millet hay* in a trial at the Michigan Station[47] by H. W. Mumford proved poorer than corn stover or oat straw. More care was necessary in feeding this hay than any other coarse fodder, as it induced scours unless fed in limited quantity. (**317**)

Western *prairie hay,* tho more palatable than timothy hay, is much inferior to alfalfa hay. (**857**) When prairie hay is fed with carbonaceous grains, as corn, larger gains will be secured by the addition of some nitrogenous supplement to the ration. This is shown by the following table, giving the average results of 2 trials at the Wyoming[48] and 1 at the Nebraska Station:[49]

Value of supplement with prairie hay and corn

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Hay Lbs.
Lot I, total of 45 lambs				
Prairie hay, 1.2 lbs.				
Shelled corn, 0.9 lb	64	0.19	485	628
Lot II, total of 45 lambs				
Prairie hay, 1.3 lbs.				
Shelled corn, 0.8 lb.				
Oil cake or meal, 0.2 lb	64	0.23	451	547

Lot II, fed oil meal in addition to prairie hay and corn, made larger gains than Lot I, receiving the unbalanced ration, and required 34 lbs. less grain and 81 lbs. less hay for 100 lbs. gain. When corn or other carbonaceous grains are very low in price compared with all nitrogenous concentrates, the unbalanced ration may prove more profitable for the feeder, even tho the lambs make less rapid gains.

Sorghum hay ranks with corn stover, its value depending to a large extent upon its fineness. Burnett of the Nebraska Station[50] has shown that some nitrogenous supplement, such as linseed meal, should be added to a ration of corn and sorghum hay for the best results. (**308**)

862. Corn stover and corn fodder; straw.—Next in value to hay from the legumes come the dry leaves of the corn plant. For sheep feeding, corn should be cut early and cured in well-made shocks. The sheep will eat a little more of the stalks if shredded, but cutting will not induce them to eat any of the coarser parts. (**294-5**) That neither corn stover nor straw should form the sole roughage for sheep is shown in the following table, which gives the average results secured by Carmichael and Hammond[51] at the Ohio Station in 2 trials, lasting 93 and 83 days, and presents the data obtained by McDonald and Malone in a 140-day test with lambs at the Oklahoma Station:[52]

[47] Mich. Bul. 136.
[48] Wyo. Buls. 73, 89.
[49] Nebr. Bul. 66.
[50] Nebr. Bul. 71.
[51] Ohio Bul. 245.
[52] Okla. Bul. 78.

Corn stover and oat straw for fattening lambs

Daily roughage allowance	Concentrates fed daily		Daily gain	Feed for 100 lbs. gain	
	Corn	Cotton- or linseed meal		Concentrates	Dry fodder
Ohio trials	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I, Clover hay, 1.2 lbs......	1.3	....	0.32	389	383
Lot II, Corn stover, 1.4 lbs.....	1.1	0.21	0.28	453	485
Lot III, Oat straw, 1.1 lbs.......	1.1	0.21	0.24	527	447
Oklahoma trial					
Lot I, Alfalfa hay, 1.5 lbs......	1.6	....	0.36	454	411
Lot II, Corn stover, 0.8 lb...... Alfalfa hay, 0.7 lb......	1.2	0.40	0.34	479	426

While making fair gains and showing fair finish, the Ohio lambs fed stover consumed 16 per ct., and those fed oat straw 35 per ct., more concentrates for 100 lbs. gain than Lot I, fed clover hay. Carmichael and Hammond conclude that at the prevailing prices for feeds and lambs, it is unprofitable to feed either corn stover or oat straw as the sole roughage. In the Oklahoma trial, tho fed for an unusually long period, both lots of lambs made exceedingly good gains. Lot II, fed corn stover and alfalfa hay, made practically as large gains as Lot I, receiving twice as much alfalfa hay. The amount of concentrates required by this lot for 100 lbs. gain was also but little more than with Lot I.

Coffey[53] of the Illinois Station states that experienced Michigan sheep feeders give oat straw at one feed and alfalfa hay at the next, claiming that the lambs so fed gain as well as tho alfalfa formed the sole roughage. With yearling wethers Coffey[54] secured daily gains of 0.26 lb. per head on a ration of shelled corn, corn silage, and oat straw, and 0.25 lb. on shelled corn, silage, and corn stover, in comparison with 0.29 lb. on corn, alfalfa hay, and silage, and only 0.15 lb. on corn and oat straw alone. This trial shows clearly that for the best results straw should be fed with other more palatable roughage, especially succulent feed. Such good gains with rations as low in protein would have been impossible with lambs, which are growing as well as fattening. These trials show that, judiciously fed, such cheap roughages as corn stover and oat straw may lower the cost of mutton production. (**296, 328**) Shaw[55] advises that when both legume hay and some other less palatable roughage are fed, the legume hay be given for the evening meal.

Shock corn may be fed to sheep with satisfactory results, as is shown in a trial by Coffey[56] at the Illinois Station, which has been previously reviewed. (**847**) Whether it will be more profitable to feed shock corn or to husk and shell the corn before feeding will depend on the price of feeds and labor.

[53]Breeder's Gaz., 66, 1914, p. 85.
[54]Information to the authors.
[55]Management and Feeding of Sheep, p. 212.
[56]Information to the authors.

III. Succulent Feeds

863. Value of succulent feeds.—One of the advantages of succulent feeds, so keenly relished by sheep, is their tonic and regulating effect. Roots are universally fed in large amounts to sheep in Great Britain, and to this fact may be attributed much of the reputation of the British shepherd for producing mutton of the highest quality. As is shown in the following articles, experiments in this country have proved that roots can be successfully replaced by corn silage, which is produced at lower cost in most sections of the United States. **(109)**

864. Roots.—The value of roots for fattening lambs is shown in the following summary of 5 trials, averaging 113 days, in each of which 1 lot was fed roots in addition to an already excellent ration of grain (chiefly corn) and either alfalfa, clover, or mixed clover and timothy hay.

Value of roots for fattening lambs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Grain Lbs.	Roots Lbs.	Hay Lbs.
*Roots, total of 41 lambs**					
Roots, 3.7 lbs.					
Hay, 1.4 lbs.					
Grain, 1.4 lbs.	81	0.39	374	940	358
*No roots, total of 41 lambs**					
Hay, 1.7 lbs.					
Grain, 1.5 lbs.	82	0.32	456	...	525

*Average of 3 trials by Kennedy, Robbins, and Kildee (Iowa Bul. 110), 1 by Smith and Mumford (Mich. Bul. 113), and 1 by Arkell (N. H. Bul. 152).

In these trials the allowance of roots—mangels, sugar beets, rutabagas, or turnips—ranged from 1.9 to 5.0 lbs. per head daily, the average being 3.7 lbs. The lambs fed roots ate 0.1 lb. less grain and 0.3 lb. less hay per day but made 0.07 lb. larger daily gain. It is noteworthy that in each of the 5 trials the root-fed lambs made the larger gains. In these trials 100 lbs. of roots replaced 8.7 lbs. of grain and 17.7 lbs. of hay.

In trials at the Iowa Station by Kennedy, Robbins, and Kildee[57] sugar beets ranked first in amount and economy of gain, with mangels second, and turnips third. Since mangels and sugar beets when fed to sheep tend to produce calculi, or stones, in the kidneys or bladder, which are dangerous in the case of rams and wethers, these roots should not be fed to males for long periods. In the Iowa trials rams died after being fed on rations containing 4.4 lbs. of sugar beets or mangels for 5 to 6 months. Ewes are not so affected. **(365-74)**

865. Lessons from Great Britain.—The value of succulent feed in the form of roots for sheep fattening is well shown in the compilation made by Ingle of the results of sheep-feeding trials reported in Great Britain[58] from 1844 to 1905, numbering 194. From his extended report the following typical examples show the use British farmers make of roots in fattening sheep and lambs:

[57] Iowa Bul. 110. [58] Trans. Highl. and Agr. Soc. Scotland, 1910.

Rations used by British farmers in fattening sheep and lambs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Total gain per head Lbs.
Oxford-Hampshire lambs, fed 87 days			
Roots, 5.7 lbs.			
Kohlrabi, 11.2 lbs.			
Clover hay, 0.38 lb. Linseed cake, 0.7 lb.	117	0.48	43
Leicester-Blackfaced lambs, fed 105 days			
Swedes, 15.3 lbs.			
Hay, 0.7 lb. No concentrates	80	0.21	22
Oxford lambs, fed 102 days			
Swedes, 22.9 lbs. Linseed cake, 0.3 lb.			
Hay, 0.4 lb. Barley, 0.3 lb.	107	0.43	42
Cotswold yearlings, fed 121 days			
Roots, 15 lbs.			
Hay, 1.0 lb. Cottonseed cake, 1.6 lbs.	111	0.33	41
Leicester-Blackfaced lambs, fed 63 days			
Swedes, 19.3 lbs. Dried dist. grains, 0.5 lb.	72	0.39	25
Leicester-Blackfaced lambs, fed 105 days			
Swedes, 12.8 lbs. Linseed cake, 0.7 lb.	81	0.36	37

Not only is the large allowance of roots noteworthy, but also the almost universal use of oil cake—linseed or cottonseed. The gains reported in the first trial are surprising, considering that the only concentrate fed was 0.7 lb. linseed cake per head daily. In the second trial fair gains were secured on swedes and hay alone. In the last 2 trials the lambs fed no dry roughage, but only roots and dried distillers' grains or linseed cake, made excellent daily gains.

Altho these British trials show that large amounts of roots may be safely fed to sheep, it is not ordinarily profitable in this country to feed over 4 to 5 lbs. per head daily, and even half this allowance, preferably pulped or sliced, will furnish the needed succulence in the ration.

866. Corn silage vs. roots.—Owing to the low cost of producing corn silage, the possible substitution of this succulence for roots is a question of prime importance. The following table summarizes the results of 7 trials, averaging 116 days, in which corn silage and roots (sugar beets, mangels, rutabagas, or turnips) were compared, when fed with concentrates and legume or mixed hay:

Corn silage vs. roots for fattening lambs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain: Concentrates Lbs.	Hay Lbs.	Succulence Lbs.
*Silage, total of 72 lambs**					
Corn silage, 3.0 lbs.					
Hay, 1.3 lbs.					
Concentrates, 1.2 lbs.	89	0.30	396	439	1,040
*Roots, total of 90 lambs**					
Roots, 4.6 lbs.					
Hay, 1.5 lbs.					
Concentrates, 1.2 lbs.	89	0.32	380	471	1,507

*Average of 3 trials by Grisdale (Ottawa Expt. Farms Rpts. 1910, 1911, 1912), 2 by Kennedy, Robbins, and Kildee (Iowa Bul. 110), and 2 by F. B. Mumford (Mich. Buls. 84, 107).

The lambs fed silage made the same gains in 2 of the trials, larger gains in 1, and somewhat smaller gains in the other 4 trials. On the average there was only 0.02 lb. difference in the daily gains of the lambs fed silage and roots. The silage-fed lambs required 16 lbs. more grain, but 32 lbs. less hay for 100 lbs. gain than those fed roots, the larger requirement of grain by the silage-fed lambs being offset by the larger consumption of hay by those fed roots. Thus, based on the feed required per 100 lbs. gain, 1,040 lbs. of silage replaced 1,507 lbs. of roots, due to the more watery nature of the roots. (**366**)

867. Corn silage.—Only in recent years has the value of corn silage for cheapening the cost of fattening sheep been appreciated. The following average of 7 trials, lasting from 70 to 105 days, in which a ration of clover hay and shelled corn was compared with one of corn silage, clover hay, and shelled corn for fattening lambs shows the benefits from adding silage to an already excellent ration:

Value of corn silage when added to well-balanced ration

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Hay Lbs.	Silage Lbs.
*Lot I, total of 147 lambs**					
Corn silage, 1.4 lbs.					
Clover hay, 0.9 lb.					
Shelled corn, 1.2 lbs.	62	0.326	360	284	425
*Lot II, total of 147 lambs**					
Clover hay, 1.5 lbs.					
Shelled corn, 1.3 lbs.	62	0.323	394	471	...

*Average of 5 trials by Skinner and King (Ind. Buls. 162, 168, 179; and information to the authors), and 2 by Coffey of the Ill. Station (Information to the authors).

On the average, the lambs fed silage ate 0.6 lb. less hay and 0.1 lb. less corn daily yet gained slightly more than those fed clover hay and shelled corn. Adding silage to a ration of clover hay and corn does not, however, always result in increased gain, for in 4 of these trials the lambs fed no silage made the larger gains. The great advantage in feeding silage lies in the saving of corn and hay required for 100 lbs. of gain. In these trials 100 lbs. of corn silage saved 8.0 lbs. of corn and 44.0 lbs. of clover hay. With corn at a cent a pound and clover hay at $10 per ton, the silage fed had a value of $6.00 per ton, or nearly twice the cost of production on most farms. (**410**) Besides cheapening the gains in these trials the addition of silage to the ration usually resulted in higher finish and consequently in a greater selling price. (**300, 411**)

Corn silage of good quality is as valuable for the breeding flock as for sheep being fattened for market. (**884**) The numerous instances in which sheep of all classes have died from eating moldy or decayed silage show that greater care is necessary in administering this feed to sheep than to cattle. As sour silage is apt to cause colic and scouring, silage for sheep should be made from well-matured corn.

868. Supplements to silage, corn and legume hay.—It has already been shown that adding a nitrogenous concentrate such as cotton- or linseed meal to an already well-balanced ration of corn and legume hay is not ordinarily profitable. (858) When corn silage is added to a ration of corn and legume hay, all being fed in unlimited allowance, the lambs will eat less of the protein-rich hay, the nutritive ratio thereby being widened to a marked degree. Skinner and King[59] conducted trials during 5 successive years at the Indiana Station with 60-lb. lambs to determine whether it would be profitable to add a nitrogenous concentrate (cottonseed meal) to such a ration. In 3 of the trials, as is shown in the table, they also determined whether it was more profitable to feed 1 part of cottonseed meal to 7 or to 4 parts of shelled corn:

Adding a supplement to a ration of corn, corn silage, and clover hay

Average ration	Daily gain	Feed for 100 lbs. gain			Nutritive ratio
		Concentrates	Hay	Silage	
	Lbs.	Lbs.	Lbs.	Lbs.	
Supplement vs. no supplement, 5 trials					
Lot I, total of 115 lambs					
Cottonseed meal, 0.16 lb.					
Shelled corn, 1.1 lbs.					
Corn silage, 1.3 lbs.					
Clover hay, 1.0 lb.	0.355	348	287	368	1:6.8
Lot II, total of 115 lambs					
Shelled corn, 1.2 lbs.					
Corn silage, 1.2 lbs.					
Clover hay, 1.0 lb.	0.331	360	299	379	1:8.8
Amount of supplement, 3 trials					
Lot I, total of 75 lambs					
Cottonseed meal, 0.15 lb.					
Shelled corn, 1.0 lb.					
Corn silage, 1.5 lbs.					
Clover hay, 1.1 lbs.	0.355	337	312	428	1:6.8
Lot II, total of 75 lambs					
Cottonseed meal, 0.24 lb.					
Shelled corn, 1.0 lb.					
Corn silage, 1.5 lbs.					
Clover hay, 1.1 lbs.	0.358	336	307	422	1:6.1

The first comparison shows that feeding 1 part of cottonseed meal with 7 parts of shelled corn increased the gains and slightly decreased the amount of feed for 100 lbs. of gain. This shows that the ration of shelled corn, corn silage, and clover hay, having a nutritive ratio of 1:8.8, was too wide for the *maximum* gains with fattening lambs. It does not imply, however, that the *most profitable* gains are necessarily produced when a nitrogenous supplement is added, for the economy of the gains will depend on the relative price of corn and the supplement. In 2 of these trials cheaper gains were produced without cottonseed meal. On the average the lambs fed cottonseed meal reached slightly higher finish and sold for 5 cts. more per 100 lbs. In 3 trials the profit was greater and in the other 2 less when cottonseed meal was fed. Whether or not to add a nitrogenous concentrate to a ration of shelled

[59]Ind. Buls. 162, 168, 179; information to the authors.

corn, corn silage, and legume hay must be determined by each feeder for himself, after taking into consideration the prices of feeds, the value of the manure, and the time the animals should be ready for the market.

The second part of the table shows that the gains were not appreciably larger when 1 part of cottonseed meal was fed to 4 parts of corn than when the smaller allowance was used. In 2 of the 3 trials the gains were cheaper on the smaller allowance of cottonseed meal. These trials indicate that a ration having a nutritive ratio of 1: 6.8 is about as satisfactory for fattening lambs as the narrower ratio of 1: 6.1.

869. Amount of silage to feed.—That corn silage should not ordinarily form the sole roughage for fattening lambs is shown by the following summary of 2 trials, averaging 95 days, conducted by Skinner and King at the Indiana Station.[60] The table further gives the results for 3 trials, averaging 94 days, 1 by Skinner and King[61] and 2 by Coffey,[62] in which the relative value of large and small allowances of corn silage were compared when fed with clover hay and shelled corn.

Amount of corn silage to feed fattening lambs

Average ration	Initial weight	Daily gain	Feed for 100 lbs. gain		
			Concentrates	Hay	Silage
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Silage vs. silage and hay, 2 trials					
Silage alone, 50 lambs					
Corn silage, 2.2 lbs.					
Shelled corn, 1.0 lb.					
Cottonseed meal, 0.14 lb.	61	0.26	431	...	856
Silage and clover hay, 50 lambs					
Clover hay, 1.1 lbs.					
Corn silage, 1.6 lbs.					
Shelled corn, 1.1 lbs.					
Cottonseed meal, 0.16 lb.	61	0.36	344	301	436
Large vs. small silage allowance, 3 trials					
Silage in small amount, 57 lambs					
Corn silage, 1.1 lbs.					
Clover hay, 1.0 lb.					
Shelled corn, 1.2 lbs.	66	0.31	379	332	360
Silage in large amount, 57 lambs					
Corn silage, 1.7 lbs.					
Clover hay, 0.8 lb.					
Shelled corn, 1.2 lbs.	65	0.32	361	268	526

In each of 2 trials averaged in the first portion of the table the lambs fed corn silage only for roughage made much smaller gains, had poorer appetites, and required more care to prevent going "off feed." Tho in the first trial silage alone produced cheaper gains, the poorer finish of the lambs resulted in a sufficiently lower selling price to more than offset the cheaper gains. In the other trial gains were cheaper and profit greater when hay was fed in addition to silage. Contrary to their find-

[60] Ind. Buls. 168, 179. [61] Ind. Bul. 168. [62] Information to the authors.

ings with steers (778), Skinner and King report that the appetite of lambs for dry roughage was not satisfied by supplying oat straw in addition to silage. They therefore conclude that for the best results legume hay should be fed with corn silage.

The second part of the table shows that the largest allowance of silage produced the most rapid, and, with feeds at the usual prices, the cheapest gains. Similar results were secured by Skinner and King[63] in 2 trials in which large or small allowances of silage were compared when fed with clover hay, shelled corn, and cottonseed meal. In each trial as good or better finish was produced by the heavy silage feeding.

Skinner and King conclude that it is best to allow the lambs all the silage they will clean up both morning and evening, with free access to legume hay. It is interesting to note that the lambs given all the silage they would eat still consumed nearly one-half as much hay as they did silage, while on similar feeds steers eat 5 to 7 times as much silage as hay. (776)

870. Silage other than corn.—Sorghum silage from plants sufficiently matured to produce silage low in acidity is satisfactory for sheep. This is shown by the results already reported (853), secured by Cochel[64] in trials at the Kansas Station in fattening lambs on sweet sorghum silage, alfalfa hay, cottonseed meal, and corn or kafir grain. In a 119-day trial by Jones of the Texas Station[65] a lot of 250 western lambs were fed a ration of 0.23 lb. cottonseed meal and 3.8 lbs. of feterita and sorghum silage during the first 59 days, during which time the average daily gain was 0.28 lb. Ground feterita was then added, the average ration during the remainder of the trial consisting of 0.35 lb. cottonseed meal, 1.0 lb. feterita, and 3.5 lbs. silage. During the last 60 days the lambs gained 0.29 lb. per head daily, requiring 121 lbs. cottonseed meal, 341 lbs. feterita, and 1,196 lbs. silage for 100 lbs. gain. While these lambs, fed silage as the sole roughage, made satisfactory gains, Jones states that it is advisable to supply some dry roughage, as otherwise the lambs are apt to go off feed.

In districts where the field pea flourishes, the whole plant may be profitably ensiled for sheep fattening. (355) In the vicinity of pea canneries fattening sheep and lambs on ensiled pea vines and pods is an important industry, especially in Wisconsin. (356) Some dry roughage, such as corn stover or hay, is supplied in addition to the silage, and grain or screenings fed, especially during the latter part of the fattening period. Tormey[66] of the Wisconsin Station reports that one winter a large feeder fed about 6,000 59-lb. lambs for an average of 94 days on a ration of 1.6 lbs. of grain, chiefly corn and screenings, 3.5 lbs. pea vine silage, and a small allowance of hay. The lambs gained 0.30 lb. per head daily on the average, requiring 541 lbs. grain and 1,147 lbs. silage for 100 lbs. gain.

[63] Ind. Bul. 162.

[64] Information to the authors.

[65] Information to the authors.

[66] Country Gentleman, 79, p. 808.

871. Wet beet pulp.—Wet beet pulp has been extensively fed to fattening sheep in the vicinity of beet sugar factories in the western states, and has proved an excellent feed. The value of an unlimited allowance of pulp and alfalfa hay, fed with and without grain, was tested by Linfield at the Utah Station[67] in a 78-day trial with the following results:

Wet beet pulp with and without grain for fattening lambs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Pulp Lbs.	Hay Lbs.
Lot I, 17 lambs					
Wet beet pulp, 3.3 lbs.					
Alfalfa hay, 1.4 lbs.					
Screenings and bran, 0.5 lb......	54	0.33	156	1,014	423
Lot II, 17 lambs					
Wet beet pulp, 3.7 lbs.					
Alfalfa hay, 1.6 lbs................	61	0.21	...	1,786	797

Lot I, fed a half-pound of concentrates with an unlimited allowance of pulp and alfalfa hay, made over 50 per ct. larger gains than Lot II, fed pulp and hay only. The feeding of 156 lbs. of grain effected a saving of 772 lbs. of wet beet pulp and 374 lbs. of alfalfa hay for each 100 lbs. of gain. In another trial[68] practically as large and decidedly more economical gains were produced with an average daily grain allowance of 0.4 lb. per head as when 0.9 lb. was fed. The Colorado Station[69] found 1 ton of wet beet pulp equal to 200 lbs. of corn for fattening lambs, tho when fed without grain it produced soft flesh and the lambs shrank excessively when shipped. Alfalfa hay contains an abundance of protein and mineral matter, in which both corn and beet pulp are deficient, and is therefore an admirable roughage to use with the pulp. Pulp is especially suitable for fattening aged ewes with poor teeth. When feeding heavily with pulp, the yards should be kept dry by proper drainage and the use of bedding. Morton[70] of the Colorado Station states that in Colorado pulp is generally fed to old ewes and wethers, rather than lambs, the pulp seeming to be too bulky to give the best results with the younger animals. Owing to its cheapness the pulp is usually fed in unlimited allowance thruout the whole fattening period. **(274)**

872. Pastures.—As sheep relish weeds and browse with avidity on sprouts and brush refused by other stock, they are helpful in cleaning up the farm, especially such by-places as lanes and fence corners. Of the permanent pastures, bluegrass is the most common in the upper Mississippi valley and eastward. **(311)** Farther south red top is prominent, and in the southern states Bermuda grass. **(314, 320)** In the West the native grasses, especially the grama species, furnish much of the grazing on the ranges, tho on mountain ranges in Idaho, Beattie of the Washington Station[71] found the food mostly herbs, and the leaves and twigs of shrubs.

[67] Utah Bul. 78.
[68] Utah Bul. 90.
[69] Colo. Bul. 76.
[70] Information to the authors.
[71] Wash. Bul. 113.

The clovers furnish valuable pasture, but great care is necessary to prevent bloat when sheep are grazed on them. (**340**, **348**) Alfalfa is especially liable to cause bloat and can be recommended as a pasture plant for but few sections, altho some skillful flockmasters suffer little loss. In some sections of the West alfalfa is utilized for winter grazing as it is then so lacking in succulence that danger from bloat is practically absent. In the humid regions care is always necessary to prevent infestation with stomach worms when permanent pastures are used.

873. Annual pastures.—Grazing sheep chiefly on annual pastures specially sown for them was first practiced in America at the Minnesota Station in 1895 by Shaw.[72] This system enables the flockmaster to maintain more animals on a given area than otherwise, favors rapid, continuous gains by providing succulent pasture from spring to fall, destroys nearly all kinds of weeds, and uniformly fertilizes the land. In one trial Shaw grazed 2 lots, each of ten 80-lb. yearling wethers, for 112 days by means of hurdles on the following succession of pastures: Winter rye, peas and oats, barley and oats, rape, kale, peas and oats. Lot II received 0.5 lb. of oats per head daily in addition to pasture, as is shown below:

Grazing yearling wethers on special crops with and without grain

Average ration	Daily gain Lbs.	Gain per head Lbs.
Lot I, Pasture	0.15	16.8
Lot II, Pasture and 0.5 lb. oats	0.24	26.9

While the gains were not large with either lot, they were all that could be expected during warm weather. Lot II gained 60 per ct. more than Lot I, which received no grain, and was in better condition at the close of the trial. The increase in gain was worth more than the grain fed. In this system grass pasture should be available during wet seasons, especially on heavy soils.

Craig[73] reports that on British farms heavily stocked with sheep, a rotation of grazing crops carries the ewes and lambs from the first of the season until weaning, after which the ewes go on old grass land and the lambs to freshly seeded land or other green crops. Lands newly seeded to grass and clover can be successfully pastured by sheep provided they are withdrawn therefrom when the ground is soft from rain and if they are not allowed to crop the young plants too closely.

874. Supplementary grazing crops.—More common than keeping sheep primarily on annual pastures is the growing practice of using various annual crops to supplement permanent pastures. The earliest grazing is usually furnished by the cereals, the best of which, according to Shaw,[74] is winter rye. Rye is also grown for fall grazing and in sections with moderate winters, winter wheat furnishes feed during the colder months. (**318**) The sorghums are useful in the plains region,

[72] Minn. Bul. 78.

[73] Sheep Farming, p. 206.

[74] Management and Feeding of Sheep, p. 171.

altho not especially relished by sheep. Where they flourish field peas, vetches, cowpeas, and crimson and Japan clover all furnish excellent grazing. (**355, 359, 357, 353, 360**) Rape is the most widely useful member of the mustard family, which furnishes several other grazing crops. (**381**) In the mild climate of the Pacific coast where it endures the winter, kale provides excellent spring feed. (**382**) In the fall kohlrabi and cabbage may be useful. (**379-80**) Both rutabagas and turnips are widely grown in Britain for grazing. Shaw suggests that these crops should be profitable for winter grazing in the southern states. (**370-1**)

Caution should be used in putting sheep onto clover or rape pasture, as both often cause bloat, which may prove fatal. When beginning to pasture these forages, the sheep should be allowed to graze but a short time the first day, and the period gradually increased till after a week they may remain continuously on the pasture. It is well to allow sheep to satisfy their hunger largely on other pasture or with hay or grain, before turning them on these crops. Even when care is taken, animals occasionally bloat, especially on sultry days following a rain. Immediate attention is then necessary to save the afflicted ones. Kleinheinz[75] of the Wisconsin Station recommends a drench of a pint to a quart of milk warm from the cow. Others place a stick in the animal's mouth, tied back of the head with a string, or resort to the trocar or knife.

875. Rape.—To determine the value of rape for lambs Shaw[76] at the Ontario Agricultural College confined 3 lots of 71-lb. lambs each to a measured acre of rape by means of hurdles. Lot II was fed oats in addition and Lot III had the run of an adjoining grass pasture. Each acre of rape lasted 15 lambs grazing thereon 58 days, during which time the gains were as indicated:

Returns from rape grazed by fattening lambs

	Daily gain Lbs.	Gain per acre Lbs.
Lot I, Rape only	0.39	344
Lot II, Rape and 0.5 lb. oats per head daily	0.40	348
Lot III, Rape and grass pasture adjoining	0.47	420

The addition of oats did not prove economical, while the value and importance of grass pasture in supplementing rape is strongly brought out by the larger gains of Lot III. From 344 to 420 lbs. of gain was made per acre of rape by these lambs. Shaw[77] concludes that feeding grain to lambs grazing on rape will not pay when bluegrass pasture is available. The economy of feeding grain when no pasture is available will turn on the relative abundance of rape and the cost of grain, as the feeding of grain should decrease the amount of rape eaten.

876. Rape vs. bluegrass.—At the Wisconsin Station Craig[78] grazed one lot of 48 lambs on a bluegrass pasture and another on rape for 4 weeks, feeding in addition 0.7 lb. daily per head of a mixture of equal

[75] Sheep Management, p. 121.
[76] Ont. Agr. Col. Rpt. 1891.
[77] Management and Feeding of Sheep, p. 197.
[78] Wis. Rpt. 1897.

parts of peas and corn. During this period the first lot consumed the rape on 0.64 acre. Both lots were then placed in pens and fed an unlimited allowance of hay and an increased grain allowance, as shown in the table:

Relative value of rape and bluegrass pasture for lambs

Pasture period of 4 weeks		Pen period of 12 weeks			
Average ration	Daily gain	Average ration	Daily gain	Feed for 100 lbs. gain	
				Grain	Hay
	Lbs.		Lbs.	Lbs.	Lbs.
I, Rape; grain, 0.7 lb.	0.37	Grain, 1 lb.; hay, 0.6 lb.	0.24	429	261
II, Bluegrass; grain, 0.7 lb.	0.24	Grain, 1 lb.; hay, 0.7 lb.	0.22	476	315

The table shows that the lambs pastured on rape did much better than those on bluegrass, both while on pasture and later when confined to feeding pens.

CHAPTER XXXII

GENERAL CARE OF SHEEP AND LAMBS—FATTENING—HOT-HOUSE LAMBS—GOATS

I. The Breeding Flock

Order, regularity, and quiet are paramount in the management of sheep. The flock should always be cared for by the same attendant, who moves among them quietly, giving notice of his approach by speaking in a low voice and closing doors and gates gently. Dogs and strangers should be kept from the pens at all times. Cleanliness is essential, for the sheep is the most dainty and particular of all farm animals. The successful shepherd is therefore gentle, patient, punctual, and cleanly at all times in the care of his flock.

877. The ewe flock.—Autumn is the time when the beginner in sheep husbandry usually makes his start, and when preparations for the succeeding lamb crop are made in flocks already established. Before the breeding season opens in the fall, all non-breeding ewes, poor milkers, those with "broken" mouths or spoiled udders, and others which are too old or otherwise past usefulness should be discarded. The reserve ewes should not be selected by looks alone, for the thinnest ones may have been brought to this condition by a heavy milk flow. As a rule a good ewe should be retained as long as she will breed. The ewes disposed of should be replaced by the yearlings picked as most promising the preceding fall while still lambs.

878. Date of lambing; gestation period.—The lamb dropped in late winter or early spring is far more valuable than one coming later. Under good management the early-yeaned lamb comes into the world with comfortable surroundings and a kind master to give attentions conducive to comfort and growth. With the coming of spring the young thing is of sufficient size and vigor to pass out with its dam and make the most of the fresh grass and genial sunshine. The early lamb is less susceptible to stomach worms and many of the evils which attack the later-dropped lambs. Early farm-raised lambs may be fattened and sold before the market is flooded with western range lambs from the feed lots. Where there are poor accommodations or cold quarters lambs should not be dropped in northern latitudes earlier than May, and not until the dams are on pasture.

The most extensive data on the gestation period of the ewe are those compiled by Humphrey and Kleinheinz[1] from the records of the flock at the Wisconsin Station, consisting mainly of ewes of the English

[1]Information to the authors.

breeds. The gestation period for 1,142 ewes ranged from 140 to 156 days, the average being 147 days. The greatest number (19 per ct.) dropped their lambs on the 146th day, followed by the 147th and 145th. Over half the entire number yeaned on these 3 days. Tessier of France[2] reports that the average gestation period of 912 ewes, doubtless of the Merino breed, was 152 days, over 75 per ct. lambing between the 150th and 154th days. This accords with the Wisconsin records, which show that the Merino and Cheviot ewes carried their lambs longer than those of the English breeds. It was further found that the gestation period for Shropshires and Southdowns was shorter than for the larger English breeds.

879. Flushing the ewes.—Altho the ewe with lamb at foot may have had good care and pasture during the summer, if she has had a large milk flow she will be somewhat run down by fall. With the farm flock it is often advisable to "flush" the ewes after their lambs are weaned and before breeding, a common practice with English flockmasters. This consists in giving an extra allowance of nutritious, highly palatable food for 2 or 3 weeks before the desired date of breeding, so that the ewes will then be rapidly gaining in flesh. Several advantages result from this practice. Not only is the ewe which is bred in a thrifty condition more certain to produce a vigorous lamb, but she is a more reliable breeder and more likely to drop twins. The flock will all breed within a briefer time if flushed, thus shortening the lambing period with its anxious hours. Craig[3] found that ewes suckling twins lost no more flesh than those with one lamb, and that twins made as rapid gains as singles; hence the advantage of twins under favorable farm conditions. On the western ranges, where but little attention can be given to the individual ewe, single lambs have given the best results.

880. The ram.—A well-built, vigorous ram should be chosen and then be so fed and cared for that he will remain virile. He needs no grain while on good pasture during summer, but beginning at least a month before breeding time some concentrate should be fed. During the breeding season he should be kept in good condition on such muscle-forming foods as bran, oats, peas, and oil meal, and not be allowed to run down thru insufficient feed or over use. On the other hand, he should never become fat. In purchasing, avoid a ram that has been fitted for shows, for such high living tends to impotence.

During the breeding season the ram should run with the ewes but a short time daily, or at night only. Where "hand coupling" is not practiced, to determine whether a ewe has been bred and at what time, the ram should be painted on the brisket with some compound which will leave a mark on the wool of the ewe.

In the winter the ram may be kept in thrifty condition on a daily allowance of 0.5 to 1.0 lb. of concentrates, with good roughage. Some succulent food is desirable but mangels and sugar beets should be avoided.

[2]Coleman, Sheep of Great Britain. [3]Wis. Rpt. 1899.

(864) Ram lambs need liberal rations of muscle-building foods, but should be given little fat-forming food. Lack of exercise injures the ram's procreative powers. Except during mating time the ram should be kept away from the ewe flock, so that he cannot annoy them.

881. The flock in winter.—Before going into winter quarters the flock should be divided into groups of the same age, sex, strength, and general characteristics. To give the highest returns a division of mutton sheep should not contain over 50 members. Aged breeding ewes should constitute one band, shearling ewes another, the ewe lambs a third, and the wether lambs a fourth. These bands should be again divided if there is a marked difference between their strongest and weakest members. Each member will then have an equal chance with its fellows at the feed trough and in enjoying comforts and attentions from the shepherd's hand, and the ration may then be adapted to the special needs of each group.

The quarters for the flock in winter should be dry, well-ventilated, and sunny. Drafts must be avoided, or trouble is sure to result. Warm quarters are not only unnecessary, but inadvisable. (832) From 10 to 15 square feet of ground space should be provided for each ewe. There should be wide doorways, lest the animals suffer injury when all attempt to rush thru at once, in true sheep fashion. Conveniently placed feed racks should furnish 15 to 24 inches of space per head.

To insure a crop of strong, healthy lambs exercise for the ewes is essential. Breeding sheep housed in winter should have access to a dry, sunny yard, well protected from wind and storm. To force the ewes to exercise on all fair days roughage may be scattered in small bunches over a nearby field. When the snow is deep, paths should be broken out with snow plow or stone boat. On stormy days the sheep should remain indoors, for wet fleeces dry but slowly in winter.

882. Wintering the breeding ewes.—When pasturage is deficient in the fall or the grass soft and washy, it is well to provide supplemental feed before the ewes are taken off pasture. This may be hay, grain, or better, such grazing crops as rape or fall rye. For the greatest economy the winter feed of the ewes should consist largely of roughages, hay from the legumes easily leading. (857) Indeed, when good legume hay is given along with an allowance of roots or silage no grain is needed until about a month before lambing time. The aim should be to bring the ewes to lambing in medium flesh and vigorous condition, thus insuring a good milk flow for the new-born lambs. The trained shepherd knows that the only safe way to determine the condition of a sheep is by "handling" its back. If he finds that the ewes are not thriving, he will add concentrates to their ration. With an ample supply of good roughage not over 0.5 lb. per head daily of concentrates is needed. While breeding ewes should not be fat, they should carry more flesh than most American farmers think proper. To winter them on only straw, or straw and hay is to perpetuate a flock that will gradually but surely deteriorate.

Both ram and ewe lambs intended for the breeding flock should receive liberal rations of muscle-building foods during the first winter to insure steady growth, but they should never receive a fattening ration. Craig[4] writes: "The growth and development of the lamb the first year of its life determines very largely the size and weight of the fleece and the vigor and power the animal will attain."

883. Concentrates for ewes.—Such feeds as oats, bran, and peas are especially suitable for breeding ewes, since they contain ample protein and mineral matter and do not tend to fatten. When legume hay is fed, carbonaceous grains, such as corn, barley, and kafir, may be used, but should preferably form but a part of the grain allowance for they are too fattening. Linseed meal and wheat bran ward off constipation, which is responsible for many of the winter troubles of the breeding flock. For this purpose 1 or 2 tablespoonfuls of linseed meal a day should suffice. (**855-6**)

The value of various concentrates for wintering breeding ewes was studied at the Wisconsin Station by Carlyle and Kleinheinz[5] with uniform lots, each of 12 ewes, chiefly of the mutton breeds and ranging from 138 to 157 lbs. Each ewe was fed 2 lbs. of mixed hay and 2.5 lbs. corn silage, with 0.5 lb. of concentrates, as shown in the table:

Comparison of concentrates for wintering breeding ewes

Average concentrate allowance	Daily gain Lbs.
Lot I, Whole oats, 0.5 lb	0.23
Lot II, Wheat bran, 0.5 lb	0.20
Lot III, Shelled corn, 0.5 lb	0.23
Lot IV, Dried brewers' grains, 0.5 lb	0.24

All rations proved satisfactory, these large ewes gaining steadily on the 0.5 lb. of concentrates. When the milk flow of the ewe after lambing was considered, dried brewers' grains ranked first. A fifth lot fed 0.7 lb. of a mixture of equal parts of corn, bran, and oats made no larger gains, tho consuming slightly more hay and silage. From these data and those following, the cost of feed required to winter breeding ewes may readily be computed.

884. Roughages and succulence.—Ewes should have an abundant supply of roughage, the legume hays—alfalfa, red and alsike clover, cowpea, and vetch—being the best. (**857-9**) Other useful roughages supplying less protein are corn fodder or corn stover, cut while the leaves are still green, prairie hay, oat hay, pea straw, oat straw, barley straw, etc. These serve best when fed with good legume hay. (**861-2**) Alsike clover is highly satisfactory. Timothy hay is unsatisfactory for it may cause serious constipation. Succulent feeds promote thrift and keep the digestive organs in condition. Chopped roots are an excellent succulence, tho corn silage, free from mold and low in acid, is equally satisfactory and usually less expensive. (**864-6**) It is not wise to supply too much succulent feed to pregnant ewes, for shepherds declare that it produces soft, flabby lambs. Tho larger allowances are sometimes successfully fed

[4] Wis. Rpt. 1897.

[5] Wis. Rpt. 1903.

when silage of excellent quality, high in dry matter, is available, Kleinheinz[6] of the Wisconsin Station recommends no more than 2 lbs. per head daily of roots or silage for ewes in lamb. At the Missouri Station during each of 2 winters Hackedorn[7] compared various roughages for ewes, when fed with and without a concentrate mixture of 6 parts shelled corn, 3 of wheat bran, and 1 of pea-size linseed cake by weight. Lots of 9 to 17 western ewes, averaging 86 lbs., were fed the rations shown in the table:

Comparison of roughages for wintering breeding ewes

Average daily roughage allowance	Daily grain allowance Lbs.	Total gain or loss per head Lbs.
Lot I, Clover hay, 3.0 lbs.	0.44	+4.9
Lot II, Corn silage, 2.1 lbs. Clover hay, 2.1 lbs.	0.45	+4.3
Lot III, Corn silage, 3.4 lbs.	0.43	+1.2
Lot IV, Corn stover, 2.4 lbs. Clover hay, 1.9 lbs.	0.40	—0.3
Lot V, Corn stover, 6.2 lbs.	0.50	—0.8
Lot VI, Corn silage, 2.4 lbs. Clover hay, 1.9 lbs.	....	—2.6
Lot VII, Corn stover, 2.3 lbs. Clover hay, 2.3 lbs.	....	—2.1
Lot VIII, Clover hay, 3.3 lbs. (One trial)	....	—3.2

Clover hay and grain, fed Lot I, and corn silage, clover hay, and grain, fed Lot II, proved the most satisfactory rations. The ewes in Lot IV, fed corn stover, clover hay, and 0.40 lb. grain daily, nearly maintained their weights and produced strong, thrifty lambs. A comparison of Lots II and IV, with III and V, shows that the ewes fed silage maintained their weight, while those fed stover lost a trifle. (867) The rations fed Lots VI, VII, and VIII, containing no grain, were quite satisfactory up to lambing, nearly maintaining the weights of the ewes. After lambing, however, it was necessary to add grain to the ration to produce a milk flow sufficient for the lambs.

At the Alabama Station Gray and Ridgeway[8] found that breeding ewes gained 1.6 lbs. per head during 106 days on a ration of 1.9 lbs. soybean hay, maintaining their weight practically as well as others fed 0.5 lb. cottonseed meal and 1.3 lbs. cottonseed hulls.

Carlyle and Kleinheinz[9] studied the value of corn forage (corn fodder and corn stover), corn silage, and roots for wintering breeding ewes during each of 2 winters at the Wisconsin Station. Lots of 12 ewes, averaging 148 lbs. and mostly of the mutton breeds, were fed 0.5 lb. of a mixture of equal parts corn, oats, and wheat bran per head daily, with the roughages shown in the table:

Corn forage, corn silage, and roots for wintering breeding ewes

Average roughage allowance	Av. daily gain Lbs.
Lot I, Corn silage, 2.9 lbs. Mixed hay, 2.1 lbs.	0.16
Lot II, Roots, 2.9 lbs. Mixed hay, 2.6 lbs.	0.18
Lot III, Corn silage, 3.0 lbs. Corn forage, 1.8 lbs.	0.09
Lot IV, Corn forage, 3.3 lbs.	0.19

[6]Sheep Management, p. 35.
[7]Mo. Bul. 120.
[8]Ala. Bul. 148.
[9]Wis. Rpts. 1900, 1901.

The ewes were satisfactorily maintained in all cases. A significant finding was that Lot I, fed corn silage, mixed hay, and grain, made practically as large gains as Lot II, getting roots in place of silage, and required 0.5 lb. less hay per head daily.

Tomhave and Severson of the Pennsylvania Station[10] report that breeding ewes were maintained satisfactorily on alfalfa hay and corn silage with 0.25 to 0.50 lb. of a mixture of 15 parts of shelled corn, 3 of oats, 2 of wheat bran, and 1 of linseed meal. When silage was fed as the sole roughage the cost of feed was reduced but a large loss of lambs resulted.

Trials by Skinner and Smith[11] at the Indiana Station and Evvard[12] at the Iowa Station likewise show the value of corn silage for breeding ewes. Corn silage and clover hay proved a more economical roughage allowance than clover hay alone.

885. Lambing time.—As lambing time approaches, the shepherd should take quarters in the sheep barn or close by, and remain in attendance until the season is over. It is wise to provide lambing pens for the ewes and their newly born lambs. Where lambs come early, the pens should be kept warmer than the quarters for the rest of the flock. Here each ewe and her new-born young remain for a couple of days until they are well wonted to each other and the lambs strong enough to look out for themselves among the flock. Then they may pass back to the flock or to quarters especially set apart for the ewes and lambs.

As they enter the world lambs of the mutton breeds often need quick, intelligent attention, which is always given by the true shepherd. The mucus should be cleaned from the nostrils and mouth of any weakling. With the first fill of milk from the dam the new-born lamb becomes comfortable, and is usually able thereafter to care for itself. The new-born unable to draw milk within a few minutes after birth should have patient, intelligent assistance; to this end the ewe must be held, and the lamb aided, all being accomplished by that kindly, sympathetic skill so characteristic of the good shepherd, but impossible of description. A chilled, new-born lamb is best warmed by immersion in water as hot as the hand can bear. When well warmed it should be wiped dry, taken to its mother, and held until supplied with her milk. Some advise[13] wrapping it in thick woolen cloths that have been warmed on a stove, and renewing these as often as they become cool. A lamb born almost lifeless may often be restored by alternately blowing gently into the mouth to start breathing, and laying it on its belly and slapping the body smartly on each side of the heart.[14] One twin is usually weaker than the other, and frequently the mother cares only for the stronger one. Here the shepherd's tact serves well in promptly helping the weakling to its full share of food.

A ewe that refuses her lamb will usually accept it if they are placed

[10]Information to the authors.
[11]Ind. Bul. 147. [12]Iowa Cir. 6.
[13]Craig, Sheep Farming, p. 193.
[14]Kleinheinz, Sheep Management, p. 47.

together in a small pen out of sight of the other sheep and the lamb helped to suckle a few times. The stubborn ewe may be confined in stanchions so that she cannot prevent the lamb sucking. In case a ewe loses her lamb, she may often be induced to adopt a twin by first sprinkling some of her own milk over it. Still more effective is tying the skin from the dead lamb upon the back of the one to be adopted.

886. Breeding studies; weight of lambs.—The following table gives the average birth weight and percentage of increase (the annual number of lambs per 100 ewes) of lambs from ewes of different breeds, as recorded during 24 years by Kleinheinz[15] with the flock at the Wisconsin Station.

Annual increase from ewes and birth weight of lambs

Breed	No. of ewes	Increase	Av. birth wt. of lambs		
			Singles	Twins (each)	Triplets (each)
		Per ct.	Lbs.	Lbs.	Lbs.
Southdown	181	154	9.15	7.70	5.50
Shropshire	448	167	9.51	7.67	6.49
Hampshire	96	156	10.61	8.23	7.10
Cheviot	81	147	9.45	7.67	8.20
Dorset	30	163	10.20	8.46	7.50
Oxford	12	183	10.42	8.18	7.12

Tho the table shows a considerable range of increase for the several breeds, data from many flocks covering a much larger number of animals, would be necessary to show definitely any real difference in this regard. These data are of interest in showing the actual increase obtained with good feed and excellent care. The single lambs averaged somewhat heavier than the twins, and the twins larger than the triplets, tho the difference is not great.

The percentage of increase was highest with ewes 4 to 6 years old, due somewhat to discarding the poorer breeders as 3-yr.-olds. After the 6th year the fecundity of the ewes lessened. The larger the ewe of a given breed the greater was the percentage of increase and the larger the lambs. To a less degree the size of the ram had the same influence.

The gestation period tended to be slightly longer with large lambs. The average birth weight of the ram lambs was about 0.5 lb. greater than of ewe lambs. Of 1,804 lambs yeaned, 900 were ewes and 904 rams. As the records grow, the more nearly do the sexes balance.

887. After lambing.—Soon after lambing the ewe should be given water with the chill removed. For 2 or 3 days but little grain should be fed, to avoid udder troubles, but she may have all the dry roughage she wishes. Close attention must be given for a few days to see that the lamb is taking milk from both sides of the udder. All surplus milk should be drawn, or better, a needy lamb helped to an extra meal. Caked udders and sore teats should receive prompt treatment.

[15]Wis. Rpts. 1902, 1907, and information to the authors.

With the demand for more milk by the lamb, the ewe's ration should be increased, for sucklings make the most economical gains. (**114**) If there is not sufficient roughage of high quality for the entire winter the most palatable and nutritious portion should be reserved until after the lambing period. Legume hay and succulent feeds are essential at this time, and more succulence can be safely fed than before lambing. The amount and character of the concentrates fed depend on the roughage, but seldom is over 2 lbs. per ewe daily necessary.

888. Ewe's milk.—In America the milk of sheep is seldom used by man, but abroad, and especially in the mountain regions of continental Europe, it is extensively employed, both for direct consumption and for the manufacture of cheese. The average composition of ewe's milk compared with that of cow's milk, is shown in the following table:

Composition of ewe's and cow's milk

	No. of analyses	Water Per ct.	Casein and albumin Per ct.	Fat Per ct.	Sugar Per ct.	Ash Per ct.
Ewe's milk (Sartori[16])	2,700	78.70	6.30	8.94	5.06	1.02
Cow's milk (König[17])	705	87.27	3.39	3.68	4.94	0.72

The table shows that ewe's milk is much richer in protein (casein and albumin) and fat, and higher in ash than cow's milk. (**265**) Ewe's milk has a peculiar, somewhat unpleasant odor and taste, is thicker, and sours more slowly than cow's milk. The fat content is extremely variable, ranging from 2 to 12 per ct.[18] The butter is pale yellow, less firm than cow's butter, and becomes rancid much quicker.

The yield of milk by sheep will vary greatly according to breed and feed. Sieglin[19] states that the East Friesian milk sheep in Germany at 2 to 3 years of age yield from 3 to 4 quarts of milk daily for 2 months after weaning their lambs, and keep up an excellent flow during the autumn months. These sheep are prolific, dropping 2, 3, and even 4 lambs, individuals lambing twice a year. Three sheep are estimated to consume as much feed as 1 cow. Ordinary sheep yield from 100 to 150 lbs. of milk per year, while the milk breeds produce from 300 to 1,400 lbs.

889. Milking qualities of ewes.—To determine the yield and composition of milk from various breeds Carlyle, Fuller, and Kleinheinz[20] at the Wisconsin Station kept lambs from their dams except at regular intervals when they were allowed to suckle. The milk yielded by the ewes was determined by weighing the lambs immediately before and after placing them with their dams.

[16]Jensen, Milchkunde und Milchhygiene, p. 18.

[17]Chem. Nahrungs- und Genussmittel, II, 1904, p. 602.

[18]See Staz. Sper. Ag. Ital. 23, p. 572; Analyst, 1893, p. 248; Fleischmann, Milchwirtschaft, 1901, p. 64; Jensen, Milchkunde und Milchhygiene, 1903, p. 17.

[19]Schäfer-Sieglin, Lehrbuch der Milchwirtschaft, 1908, p. 17.

[20]Wis. Rpt. 1904.

Daily milk yield of ewes of different breeds

Breed	Number of ewes	Av. daily milk yield Lbs.	Composition of milk: Fat Per ct.	Solids not fat Per ct.	Total solids Per ct.	Specific gravity
Oxford	2	3.1	7.7	11.0	18.6	1.038
Southdown	2	1.9	8.4	11.1	19.5	1.038
Dorset	2	4.3	7.2	10.9	18.1	1.038
Shropshire	3	2.5	5.9	10.8	16.7	1.039
Merino	3	2.3	6.0	10.8	16.8	1.038
Range	2	2.7	7.2	11.1	18.3	1.039
Average, 14 ewes		2.8	7.1	10.9	18.2	1.038

The Dorsets gave the most and the Southdowns the richest milk. On the average the milk contained over 7 per ct. fat and nearly 11 per ct. of solids not fat, its specific gravity exceeding that of cow's milk.

890. Feed for 100 lbs. of ewe's milk.—At the Wisconsin Station Shepperd[21] recorded the milk yield of ewes receiving a mixture of 3 parts wheat bran and 1 of linseed meal, with fair-quality clover hay and sliced potatoes for roughage.

Feed and water consumed by ewes for each 100 lbs. of milk produced

	Concentrates Lbs.	Clover hay Lbs.	Potatoes Lbs.	Water drunk Lbs.	Dry matter Lbs.
Single ewe	51	61.6	38	293	105
Group of 2 ewes	59	55.5	29	417	105
Group of 2 ewes	72	63.0	36	404	125

The single ewe produced 100 lbs. of milk while consuming 51 lbs. of concentrates, 61.6 lbs. of clover hay, and 38 lbs. of potatoes, containing in all 105 lbs. of dry matter. When we compare these figures with those showing the amount of dry matter required by cows for 100 lbs. of milk, (**544**) and further consider that the milk of the ewe is richer and that she is at the same time growing a fleece, the economy of her production is most striking and suggestive.

891. Value of ewe's milk for lambs.—Shepperd[22] further recorded the amount of milk consumed by lambs and their gains by weighing the lambs before and after sucking.

Daily gain of lambs and gain per pound of ewe's milk consumed

	Age Days	Gain per day Lbs.	Milk for 100 lbs. gain Lbs.
Lamb No. 1	25	0.62	641
Lamb No. 2	28	0.47	602
Lamb No. 3	36	0.44	690
Lamb No. 4	34	0.40	629
Average	31	0.48	640

The lambs made an average daily gain of nearly 0.5 lb. and consumed 640 lbs. of milk for 100 lbs. gain. Shepperd concludes that the gain of lambs, during the first month of their lives at least, is largely controlled

[21] Agr. Science, VI, p. 397. [22] Agr. Science, VI, pp. 397, 405.

by the quantity of milk they receive, and consequently that ewes should be carefully selected for their milking qualities.

892. Cow's milk for lambs.—Lambs can be successfully reared on cow's milk, tho close attention is necessary during the first month. Warm cow's milk with some cream added can be fed from a nursing bottle or a teapot over the spout of which a rubber "cot" with an opening in the end has been placed. At first the lamb should be fed 15 to 18 times in 24 hours, and later half a dozen times. At the Wisconsin Station[23] the senior author reared 4 vigorous cross-bred Shropshire-Merino lambs, 10 days old and averaging 10 lbs. in weight when the trial began, on cow's milk and other appropriate feeding stuffs. For the first 21 days whole cow's milk at blood heat constituted their sole food; later skim milk, ground oats, and green clover were supplied. During the last 21 days hay was fed in place of the milk.

Cow's milk and other feeds required for 100 lbs. gain with lambs

Period	Whole milk Lbs.	Skim milk Lbs.	Oats Lbs.	Green clover Lbs.	Hay Lbs.
1st period, 21 days	579	...	...	....	...
2d period, 115 days	...	830	119	262	...
3d period, 21 days	...	...	291	1,197	176

At the close of the last period, when 167 days old, the lambs averaged 79 lbs. each, showing a daily gain, including birth weight, of nearly 0.5 lb. each. The heavy gains which followed the use of cow's milk suggest its profitable use in forcing lambs to meet the requirements of special markets, e. g., "Christmas lambs."

893. Relative economy of lambs and pigs.—From the figures for the second period of the preceding article and those in Art. **913** the following data are deduced:

Feed required for 100 lbs. of increase by young pigs and lambs

Feed	Pigs Lbs.	Lambs Lbs.
Meal	237	119
Skim milk	475	830
Green clover	...	262
Meal equivalent	316	284

Estimating that 6 lbs. of skim milk equals 1 lb. of meal in feeding value, according to the Danish formula, (**958**) we have 316 lbs. of meal or its equivalent, as the feed required for 100 lbs. of gain with unweaned pigs. Using the same ratio for the skim milk fed to the lambs and allowing 10 lbs. of green clover to equal 1 lb. of meal, we have 284 lbs. of meal, or its equivalent, as the feed required for 100 lbs. of gain with young lambs, or 32 lbs. less than that required by the pigs. From this it is apparent that lambs make at least as economical gains for feed consumed as do pigs of the same age.

[23]Wis. Rpt. 1890.

894. The young lamb.—When about 2 weeks old the lusty young lamb will be found nibbling forage at the feed trough beside its dam, and the shepherd should provide specially for its wants to early accustom it to take additional food. This is best accomplished by having an enclosure or room called the "lamb-creep" adjoining the ewe-pen, into which the lambs find their way, while the mothers are prevented from entering because of the limited size of the openings. In this space, accessible to the lambs only, should be placed a low, flat-bottomed trough, with an obstruction lengthwise over the top to prevent the lambs from jumping into it. In the trough should be sprinkled a little meal especially palatable to the lamb, such as ground oats, bran, corn meal or cracked corn, oil meal, soybean meal—one or all—varying the mixture to suit the changing tastes of the young things. At first they will take but little, but soon they become regular attendants at the trough thru habit impelled by appetite. There should be no more feed in the trough at any time than will be quickly consumed, and any left over must be removed and the trough thoroly cleaned before the next allowance is given. Fine alfalfa or second-crop clover hay should be provided, and roots, cabbage, or good silage will be appreciated. All feed should be fresh, with no smell of the stable—that which is left over can be given to the pigs. Lambs will drink a good deal of water, and this also must be fresh and clean. Ram lambs not intended for breeding should be castrated when 1 to 2 weeks old, and all lambs should be docked, the ewes when 8 to 14 days old and the rams 5 to 7 days after castration.

895. Turning to pasture.—With the springing of the grass, ewes and lambs should be turned to pasture for a short time during the warm part of the day. It is best to accomplish the change gradually and while the grass is short. After a few hours spent in the sunshine, nibbling at the grass, the ewes and lambs should be returned to shelter, where a full feed awaits them. When the grass has become ample and nutritious, stable feeding may be dropped for ewes, or both ewes and lambs, according to the plan followed. With good pasture, breeding ewes need no grain. Indeed, we may look forward to the pasture season as marking the time to "draw the grain from their systems," as it is termed by shepherds. In some instances pasture so stimulates the milk flow of ewes that an over-supply of rich milk causes digestive derangement and sudden death with young lambs. The shepherd should forestall such trouble by removing the ewes from the pasture after a few hours grazing each day, and by giving hay or other dry feeds, thereby reducing the milk flow.

It is usually best to feed the lambs concentrates in addition to what they get from dams and pasture. To this end, at some convenient point in the pasture let there be a "lamb-creep," and in a space accessible by way of the creep a trough for feeding grain. Whenever the lamb passes thru the creep it should find something in this trough to tempt the appetite—oats, bran, pea meal, and corn meal constituting the leading articles. Williams of the Arizona Station[24] reports good results from feeding a mixture of 4 parts of corn meal, 1 of bran, and 1 of cottonseed meal to lambs running with their dams on alfalfa pasture. Grain never gives such large returns as when fed to thrifty young animals, and the growing lamb is no exception.

896. At weaning time.—Lambs of the mutton breeds, more or less helpless at birth, are lusty at 4 months of age, and will be found grazing regularly beside their dams in pasture when not at rest or eating grain within the lamb-creep. At this time they should generally be weaned, for their own good as well as to allow their dams a rest before another breeding season. Wing[25] states that it is not necessary to wean lambs of the mutton breeds before they go to market if they have been well fed, for they will reach a weight of 75 to 85 lbs. while suckling their mothers. If possible, advantage should be taken of a cool spell in summer to wean the lambs. Lambs weaned during excessively hot weather may receive a serious setback because of the heat and fretting for their mothers. The lambs should be so far separated from their dams that neither can hear the bleating of the other. For a few days the ewes should be held on short pasture or kept on dry feed in the yard. The udders must be examined, and if necessary, as is often the case with the best mothers, they should be drained of milk a few times lest inflammation arise. The lambs should be put on the best pasture and given a liberal supply of grain. New clover seeding is especially relished, while young second-crop clover is also satisfactory. An especially choice bite may always be provided for the lambs at this important time by a little forethought on the part of the shepherd.

897. After weaning.—Fresh, nutritious pasture should be provided for the lambs after weaning. Besides clover, rape is especially suitable. Other forage crops may also be employed in sections where they thrive. Lambs that are to be marketed early or those being fitted for shows will utilize a grain allowance with profit. For those to be fattened in winter or for the ewe lambs to be retained in the flock grain may not be necessary when grazing is good. Ram lambs require grain during the fall to secure proper development, whether they are to be sold as lambs or retained till yearlings. Naturally the concentrate allowance for the lambs destined for the breeding flock should supply a greater proportion of protein than is necessary for those being finished for market.

898. The stomach worm.—In the territory east of the Mississippi river the stomach worm, *Strongylus contortus,* is a serious menace to sheep raising, lambs being especially susceptible to attack. The eggs of the parasite pass in the droppings of the sheep and are scattered about the pastures, where they soon hatch. Sheep become infested only by swallowing the worms while grazing. Fields on which no sheep, cattle, or goats have grazed for a year, and those that have been freshly plowed and cultivated since sheep grazed thereon, are practically free from infes-

[24]Information to the authors.

[25]Sheep Farming in America, p. 149.

tation. Old bluegrass pastures are especially to be avoided. It is also dangerous to allow sheep to drink from stagnant pools. During warm weather, otherwise clean pastures may become infested in from 3 to 14 days by grazing sheep thereon.

To remove the worms from the intestinal tract of sheep, various drenches are recommended, the one most commonly used being 1 tablespoonful of gasoline, thoroly mixed with 5 to 6 ounces of fresh cow's milk, with a tablespoonful of raw linseed oil added. The above dose, suitable for a lamb of average size, should be increased for older sheep. The treatment should be repeated each day for 3 days. With weak lambs the doses may be given on alternate days.

Tho remedies are of value, prevention of infestation has proved more successful. Kleinheinz[26] of the Wisconsin Station recommends the following system of handling sheep and lambs: In the northern United States worm-free and infested sheep may graze together in a clean field at any time from the last of September until May with little danger. From June to September change to fresh, clean pasture every 2 or 3 weeks. Annual pastures, as rape, clover seeding, etc., are well adapted to this system. This effective method requires several separate, clean pasture lots. In the warmer sections the sheep should be changed to clean pasture earlier in the spring and more frequently during the summer. Thoroly treating the ewes with some vermifuge will remove most of the worms, and aid in preventing infestation. Farmers often make the serious mistake of allowing the lambs to remain with their dams after weaning. Instead, they should at once be placed on fresh, clean pasture on which no sheep have previously grazed that season. Nothing is better than turning the lambs into a field of well-matured rape connecting with a fresh grass pasture. Well-fed, thrifty sheep and lambs can much better resist parasites than those getting poor feed and care.

II. Hints on Fattening Sheep

899. Hints on sheep feeding.—Sheep feeders do not begin operations at an early hour in winter, preferring not to disturb the animals until after daybreak. Usually grain is first given, followed by hay and water. The trough in which grain is fed should be kept clean at all times, and there should be ample space, so that each animal may get its share of grain. As has been previously pointed out in this chapter, regularity and quiet are of especial importance with fattening sheep. Faville of the Wyoming Station[27] reports that during a certain 2-week period of a feeding trial 160 lambs fed by McLay, a most experienced shepherd, made a total gain of 475 lbs. During the next 2 weeks McLay was absent. Tho his place was taken by a man who followed the "letter of the law" the lambs lost 85 lbs. in the 2 weeks, several going off feed. The regular shepherd then returned and in the next 2 weeks the lambs gained 508 lbs.

[26]Sheep Management, p. 111. [27]Wyo. Bul. 89.

Nowhere does the skill of the feeder show more plainly than in getting sheep to full grain feed without getting a single one off feed. Western sheep may not be able at first to take over 0.1 lb. of grain per day. If so, 2 months or 10 weeks may be required in getting the flock to full feed. English mutton sheep take grain more readily, and in some cases no more than 3 or 4 weeks need intervene between placing the lambs on feed and full feeding. In no case should this operation be hurried, for it means waste of feed and injury if not loss of some of the animals.

In all cases before sheep are admitted to the fattening pens they should be examined by an experienced shepherd, and if any evidence of skin disease or vermin is found the flock should be dipped in the most thoro manner. In the West scab and in the East lice and ticks are common troubles. To attempt to fatten sheep afflicted with any of these pests is to court disaster. Ticky sheep show increased irritability and restlessness as soon as fattening begins.

900. Length of feeding period.—The feeding period with sheep and lambs which have never received grain while on pasture should last from 12 to 14 weeks, according to their condition in the beginning and the rapidity with which they gain. The tables in the preceding chapter show that lambs increase in weight at least a quarter of a pound per day when gaining normally. For a feeding period of 100 days the gains should run from 25 to 30 lbs. per head. This weight, mostly fat, added to the carcass of a lamb weighing originally 60 to 80 lbs., brings it to the size desired by the market. Formerly the market called for a large lamb, but now the demand is for plump ones weighing from 80 to 90 lbs., or even less if they are from the western ranges. As soon as lambs are ripe, or when the backs and the region about the tail seem well covered with fat, they should be sold, for further gains cannot be made at a profit. Ripe lambs fed a heavy grain ration at the North Dakota Station[28] gained only 0.8 lb. each in 4 weeks, returning a heavy loss instead of profit.

901. Rations for fattening lambs; cost of gains.—From the many trials reviewed in the preceding chapter the feeder can readily determine the best combination of feeds to employ under his local conditions. The tables showing the amount of feed required for 100 lbs. gain will enable him to compute the approximate cost of gains with feeds at market prices. It should be remembered that the results presented were secured with thrifty lambs, fed by skilled feeders and under good conditions. The feed required for a given gain will therefore often exceed the amount stated. Comparing the cost of gains, it will be found that lambs give better returns for the feed supplied than do steers. The gains of mature sheep will cost from 25 to 30 per ct. more than those of lambs.

902. Proportion of concentrates.—Thruout the corn belt and the eastern states lambs are commonly fed all the grain they will clean up after being brought to full feed. On the other hand, in the West, where hay

[28] N. D. Bul. 28.

is cheap compared with grain, the allowance of grain is often restricted. At the Illinois Station[29] Coffey conducted the following trials lasting 90 and 98 days, respectively, with lots each of 20 western lambs, to determine the effect of feeding various proportions of shelled corn and alfalfa hay:

Feeding various proportions of shelled corn and alfalfa hay to lambs

Average ration		Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Hay Lbs.
First trial					
Lot I, Corn, 1.2 lbs.	Alfalfa hay, 1.2 lbs.	69	0.30	412	408
Lot II, Corn, 1.0 lb.	Alfalfa hay, 1.4 lbs.	69	0.27	389	527
Lot III, Corn, 0.7 lb.	Alfalfa hay, 1.7 lbs.	69	0.22	327	791
Lot IV, Corn, 0.5 lb.	Alfalfa hay, 1.9 lbs.	69	0.20	266	918
Second trial					
Lot I, Corn, 1.4 lbs.	Alfalfa hay, 1.2 lbs.	65	0.33	411	353
Lot II, Corn, 1.1 lbs.	Alfalfa hay, 1.5 lbs.	65	0.32	356	466
Lot III, Corn, 0.9 lb.	Alfalfa hay, 1.8 lbs.	65	0.29	299	606

In each trial the rate of gain increased with the amount of corn fed, tho the difference was not great between Lots I and II in each trial. Coffey concludes that except with very high-priced corn and cheap hay, the cost of gains is usually less and the profit greater when the lambs are full fed on corn.

At the New Mexico Station[30] Simpson found that when lambs were fed allowances of corn ranging from 0.25 lb. to 0.90 lb. per head daily with alfalfa hay, the lambs fed the heavier allowances of grain made more rapid gains and reached a better finish. On a market which paid a premium for well-fattened lambs the heavier corn allowances would have been the more profitable. Simpson states that the time required to finish the average lambs is about as follows: With a heavy corn allowance, 70 to 80 days; with a medium corn allowance, 90 to 100 days; with a light corn allowance, 100 to 110 days; with alfalfa alone, 110 to 120 days. On alfalfa alone lambs can hardly be brought to the same finish as on grain, hence many western feeders use hay alone during the first of the fattening period and then add grain to finish the lambs and harden the flesh.

903. Fattening lambs in the fall.—Finishing lambs for market in the fall is the common practice with farmers who raise their own lambs and many who rely on buying feeder lambs from the western ranges. Until cold weather sets in the lambs may be grazed on rape or other pasture, being fed grain in addition. Thrifty lambs placed on feed in the fall should be ready for sale in December or early in January, a season when there is usually a scarcity of good lambs on the market, since the grass-fed lambs have been marketed and those in winter feed lots are not yet finished.

In some sections train loads of lambs are annually distributed in August among the farmers of a neighborhood and by them given the run of the stubble fields from which the small grain has been harvested.

[29] Ill. Bul. 167. [30] N. Mex. Bul. 79.

Often rape has been sown on the fields to increase the herbage, the seeding not taking place until the small grain is well above ground, lest the rape grow so large as to injure the grain crop. The stubble fields well cleaned, the lambs are shifted to the fields of standing corn, where they feed on the lower leaves of the corn and on rape or turnips sown at the last cultivation of the corn, finally eating more or less of the corn on the ears.

904. Fattening lambs in the western states.—Thruout the western states, especially in Colorado, large numbers of lambs and older sheep are fattened annually. Alfalfa hay is the chief roughage, with wet sugar beet pulp in the vicinity of beet sugar factories. In Colorado corn is the chief grain fed, while farther north and west larger use is made of the small grains, especially barley. The whole western range is drawn on for feeders, and the small fine-wool type of earlier times has been largely replaced by the cross-bred lamb of better mutton quality. Formerly many mature wethers were fed; but now mostly lambs are fattened.

In large feeding plants the corral, or enclosure, is commonly divided into 2 rows of lots with a lane between, each lot accommodating from 400 to 500 lambs. No shelter is provided, but windbreaks are desirable. The hay is usually fed in the lanes, 12 to 14 feet wide, extending between the lots. The low fences bordering the lanes have a 7 or 8 inch space between the first and second boards, thru which the lambs feed on the hay. About 1 running foot of lane fencing and feed troughs is allowed each sheep. The hay from the stacks is hauled down the lanes and piled along the fences, being pushed up to them 2 or 3 times a day as it is eaten away.

All lots are provided with flat-bottomed troughs for feeding grain. There is an extra or vacant lot at one end of each row of lots, likewise provided with troughs. At feeding time grain is placed in the troughs of this extra lot and the lambs from the adjoining lot are turned in. As soon as a lot is vacated, grain is put in the troughs of this lot, and the lambs enter from the next lot, and so on. At the next meal feeding begins by using the vacant lot at the other end of the row, reversing the process. After a week or more of preliminary hay feeding, corn feeding is begun. At first only a very little corn is sprinkled in the troughs, but as the lambs get used to it the amount is gradually increased until after about 2 months the lambs are on full feed, which is from 2 to 3 bushels of corn per 100 head daily. The feeding yards are usually located on streams or ditches which supply running water. Those on high ground have watering troughs into which the water is pumped. Salt is liberally furnished in troughs.

Most of the Colorado lambs are marketed unshorn. If feeding continues until late in the spring the lambs are usually shorn 6 weeks before shipping. They will then gain enough more to make up the weight of the wool removed, will pack more closely in the car, and shrink less in shipping. Gains of from 15 to 30 lbs. per head are secured by this method of fattening. With favorable markets and low-priced feed enormous profits are made, but sometimes heavy losses occur. Under this system often little or no use is made of the manure produced. As has been mentioned in the preceding chapter (860), large numbers of lambs are fattened on field peas in certain districts of the West, especially the San Luis Valley in Colorado.

905. Feeding small bands.—Fattening great numbers of lambs at a single point reached its zenith years ago when corn and wheat screenings ruled low in price, and the large operator suffered little competition from the ranchman and farmer in finishing range lambs for the market. Now conditions have changed. The price of feed has increased, and the fattening of range lambs in smaller bands has rapidly developed in the western states, in the corn belt, and farther eastward. Most fortunately for a conservative agriculture, the large operator, who often receives no benefit from the great accumulation of rich manure in the feed lot, cannot compete with the farmer who fattens one or more carloads of lambs and uses the manure for enriching his land. Prudent farmers rightly hold that enough fertility is returned to their land thru the feed lot to pay the entire labor cost of feeding. As sheep and lamb fattening on range and farm increases, the gradual decline of the old feed lot is assured.

906. Fattening lambs in the corn belt.—Tho many extensive feeders in the corn belt each annually fatten thousands of lambs, for the reasons mentioned in the preceding paragraph the tendency is toward feeding small bands. In the corn belt, shelter is required to protect the lambs from the winter storms. While too much exercise decreases the gain, the lambs are commonly allowed the freedom of small yards. In the western states the allowance of grain is often limited, so that the lambs will consume more hay, but in the corn belt they are commonly brought to full feed as soon as can be done with safety.

907. Fattening in the East.—In the eastern states an intensive system of feeding has been developed, in which the lambs are kept in pens in a barn or shed, never being turned out for exercise. The grain troughs are protected by vertical slats in such a manner that there is just room for a lamb to feed in each opening, and a single space is provided for each lamb. The lambs are brought to full feed as rapidly as possible and are given as much grain as they will clean up until ready for market. With this heavy feeding and the small amount of exercise care must be taken to keep the lambs quiet and a feeding space must be closed up whenever a lamb is removed from the pen, for excitement or overeating will cause heavy losses from apoplexy.

III. Hot House and Spring Lambs; Goats

During recent years an increasing demand has developed for winter, or "hot house" lambs. The term "hot house" lambs does not mean that they are reared in artificially heated quarters, but has been applied because the lambs are produced at an unusual season and are hence comparable to the out-of-season products of hot houses. The greatest obstacles to success in this specialty are getting the ewes to breed sufficiently early, and producing carcasses which meet the exactions of the epicure. The demand for winter lambs prevails from the last of December to Easter, the price usually being the best between New Year's and the first of April. The condition of the carcasses of such lambs is more important than their size. They must be fat and present a well-developed leg of mutton with plenty of tender, juicy lean meat and a thick caul to spread over the exposed flesh of the carcass when on exhibition. Winter lambs should weigh alive from 45 to 60 lbs. Large but lean and bony ones present a staggy appearance and bring unsatisfactory prices. Early in the season small lambs top the market, but later the heavier ones are in demand.

908. Breeding for winter lambs.—The ewes best suited for winter lamb production are pure-breds or grades of the Dorset, Tunis, and Merino or Rambouillet breeds, for the other breeds can not usually be depended on to breed sufficiently early.[31] However, Hampshires, Shropshires, and Southdowns are occasionally used with success.

At the Minnesota Station,[32] in trials covering 6 years, Shaw found that the breeding habit of common grade ewes which usually drop their lambs in the spring may be so changed by 2 or 3 generations of judicious crossing and the selection of the early yeaned lambs for breeders that they will drop lambs in fall and early winter. This change can be hastened and more permanently fixed by mating the ewes with pure-bred Dorset rams. Where the ewes have the early breeding habit well fixed, superior lambs may be obtained by using dark-faced rams, such as Shropshire and Southdown. Shaw further found that ewes which have suckled winter lambs breed more readily before being turned to grass than subsequently, especially when fed a stimulating grain ration while still in the shed. At the New York (Cornell) Station[33] Dorset ewes bred earlier, stood forced feeding better, and were less affected by unfavorable weather than Shropshire ewes, and their lambs made more rapid gains. Miller and Wing[34] advise using a young ram, well fed during service but not too fat, turning him with the ewes not earlier than the middle of March nor later than the middle of May. The ewes should be in good condition and so fed as to be gaining in flesh. Even with favorable conditions, all the ewes will not breed at the desired time, and to secure 400 winter lambs about 500 ewes are necessary. Ewes which fail to breed are sold early, and those breeding late drop lambs useful for later sales. Ewes which are successful breeders are kept as long as possible, since those lambing in November are likely to breed at the right time the following year.

909. Care of the ewe.—During the summer the ewes need abundant

[31] Wing, Savage, and Tailby, N. Y. (Cornell) Bul. 309.

[32] Minn. Bul. 78. [33] N. Y. (Cornell) Bul. 88. [34] The Winter Lamb, p. 6.

pasture, water, and shade. Should the grass become scant, they should receive additional feed—rape, pumpkins, etc. If in good condition it is rarely necessary to feed grain before lambing, and then only in small amount. The ewes should be shorn in the fall or as early in winter as possible so as to keep them cool. At weaning time the ewes should be removed to the lambing pen and fed lightly for a few days. The lambing pen should be warm so that the new-born lambs may not be chilled. Alfalfa and clover hay with silage or roots serve best for roughage, while oats, bran, oil cake, and corn prove suitable concentrates. The object at all times is to produce the largest possible flow of milk to hasten the lamb's growth. In trials at the Ohio Station[35] Hammond found a mixture of 4 parts corn and 1 part linseed meal and another of 5 parts corn, 2 parts oats, 2 parts bran, and 1 part linseed meal of about equal value when fed with alfalfa hay and corn silage to ewes raising winter lambs. Corn as the sole concentrate resulted in as good gains by the lambs, but the ewes lost in weight while others fed corn, oats, bran, and linseed meal gained.

910. The lambs.—A creep should be provided and the lambs taught to eat from a trough as soon as possible. To this end, a little sugar may sometimes be sprinkled on the grain to render it specially palatable. The lambs begin to eat freely when 2 or 3 weeks old, and are forced on bran, cracked corn, linseed meal, ground oats, barley, gluten feed, etc. They should be induced not only to eat, but to eat a large quantity, and to keep eating. Alfalfa, clover, or soybean hay is indispensable, while roots and silage are helpful. The feed troughs should be cleaned each morning, and the grain and hay supply be changed 2 or 3 times a day. When necessary, lambs are fed new milk from a nursing bottle or from a teapot having a punctured rubber cot placed on the spout. Ewes bereft of their lambs thru sale are given one of a pair of twin lambs. Thus forced, the best lambs weigh from 50 to 60 lbs. alive at 10 to 12 weeks. For the eastern markets the lambs are "hog dressed," i. e., the feet and all the viscera, except the heart, liver, and kidneys, are removed, but the pelt and frequently the head left on. The caul fat is carefully spread over the exposed parts, and the carcass sewed up in muslin after thoroly cooling. To be profitable, winter lambs must sell for not less than $5 per head, and the best ones sometimes bring as much as $12. This specialty can be conducted with profit only by experts who have gained their experience thru patient and discreet effort, and who have nearby markets that will pay the high prices such products must command.

911. Spring lambs.—A less intensive system than the preceding is the production of spring lambs. These should be dropped from January to March and are usually marketed in May and June, weighing 65 to 90 lbs., at a time of the year when there is a good demand for lambs. Raising spring lambs is especially profitable in Tennessee, Kentucky, Virginia, and states to the southward, for here the ewes may be largely

[35] Ohio Bul. 270.

maintained on pasture thruout the year, greatly lowering the feed bill. Quereau[36] writes that in the Cumberland plateau ewes are pastured in summer and allowed to run on the fields after the crops are removed. Winter crops, such as oats, barley, wheat, vetch, and crimson clover, are planted for winter and spring pasture. The sheep receive little if any grain, but during periods of bad weather are run under a shed and fed hay or other roughage.

912. Goats.—The raising of Angora goats for their mohair has become an industry of considerable importance in certain districts of the United States, especially Texas, New Mexico, Arizona, Oregon, and California. According to the census of 1910 there were over a million goats in Texas and about half a million in New Mexico. In the western states the goats graze upon rough land, utilizing browse which even sheep would refuse. In the cut-over districts of the North, Angora goats are useful in clearing land of brush at a low expense.

In Europe the milch goat is of importance as a milk producing animal, there being over 3,000,000 milch goats in Germany alone.[37] By their habits of life they are peculiarly adapted to the needs of the peasants, or poorer classes, of these countries, and have hence been appropriately termed "the poor man's cow." While the quality of the milk may be injured if the goat is maintained largely on weeds, kitchen waste, and other refuse, yet they can utilize much feed which would otherwise be wasted about the household. As with cows, the milk yield of goats varies widely. A good milch goat should continue to produce for 8 to 10 months, and yield 2 quarts of milk or more daily. The milch goat produces somewhat more milk, based upon body weight, than the cow, often yielding 10 times her body weight annually, and also requires less feed to produce 100 lbs. of milk, tho the milk is higher in fat than average cow's milk. The milch goat has not yet attained any importance in this country, but it should have a place in supplying fresh, pure milk for households in our cities. The general principles of feeding and care which have been presented for sheep also apply to goats.

[36] Tenn. Bul. 84.

[37] Thompson, Angora Goat Raising and Milch Goats, p. 177.

CHAPTER XXXIII

GENERAL PROBLEMS IN SWINE HUSBANDRY

Because of the economy with which the pig converts its food into edible flesh, this animal steadily increases in importance as our population becomes more dense. (**132-3**) Practically every farmer should raise and fatten pigs, for family consumption if not for the market, in order to profitably conserve valuable nutritive material that would otherwise be wasted. We should dismiss the idea that profitable hog raising belongs to the corn belt only. Denmark raises no corn, yet produces more pork of the highest quality than any other equal area in the world. The southern states still buy vast quantities of pork from the North despite the fact that their experiment stations have demonstrated that it can be produced at lower cost in the South. Pigs produce a pound of gain from 4 to 5 lbs. of dry matter while fattening cattle require from 10 to 12 lbs. The pig yields from 75 to 80 per ct. of his live weight as dressed carcass; the steer only 55 to 65 per ct. (**717, 726**) Pigs will profitably utilize many by-products of the farm otherwise lost, such as dairy by-products and kitchen and garden waste, as well as grains that cannot otherwise be profitably disposed of. No other line of stock farming can so quickly be brought to profitable production with limited capital invested in stock and equipment as can the making of meat from the pig. In many cases the grower should not only fatten his pigs but also slaughter them and market the cured products, obtaining increased profits even tho the undertaking be a small one.

In this book we have generally used the word "pig" rather than "hog," thereby following the usage of English farmers, for we regard the pig as the young, and the hog as the really mature animal among swine. In modern pork production swine are usually mere pigs in age when they are finished for the market and therefore such usage of the word is reasonable.

913. Rate and economy of gains by pigs.—The economy with which pigs of different weights convert feed into meat is shown in the following table summarizing the data from over 500 feeding trials with more than 2,200 pigs at many American experiment stations. In this table 6 lbs. of skim milk or 12 lbs. of whey are rated as equal to 1 lb. of concentrates.

The table shows that pigs weighing under 50 lbs. consumed on the average 2.2 lbs. of feed daily, while 300-lb. pigs consumed 7.5 lbs. daily. Based on weight, the 50-lb. pigs consumed 6.0 lbs. of feed per 100 lbs. of body weight, while 300-lb. pigs consumed only 2.4 lbs. per 100 lbs. In other words, young pigs consume far more feed for their weight than do large ones. The average gain per day started at 0.8 lb. for pigs under 50 lbs. each, and gradually increased until those weighing 250 lbs. showed a daily gain of 1.5 lbs. The last column shows that pigs weighing less than 50 lbs. each gained 100 lbs. for every 293 lbs. of feed or feed equivalent consumed, and that the quantity of feed required for 100 lbs. gain steadily increased as the pigs became larger, until at 300 lbs. weight it required 535 lbs. of feed to make 100 lbs. of gain. The great economy of young, growing pigs over older and more mature ones for making gain from a given quantity of feed is plainly brought out by the table. (**114**) When we compare the amounts of feed required for 100 lbs. gain by pigs of the different weights with the amounts required by beef cattle and sheep, the superiority of the pig as a meat producer is most striking.

Relation of weight of pigs to feed consumed and rate of gain

Wt. of pigs	Actual av. wt.	No. of animals fed	Av. feed eaten per day	Feed eaten daily per 100 lbs. live weight	Av. gain per day	Feed for 100 lbs. gain
Lbs.	Lbs.		Lbs.	Lbs.	Lbs.	Lbs.
15 to 50	38	174	2.2	6.0	0.8	293
50 to 100	78	417	3.4	4.3	0.8	400
100 to 150	128	495	4.8	3.8	1.1	437
150 to 200	174	489	5.9	3.5	1.2	482
200 to 250	226	300	6.6	2.9	1.3	498
250 to 300	271	223	7.4	2.7	1.5	511
300 to 350	320	105	7.5	2.4	1.4	535

In trials by the senior author at the Wisconsin Station,[1] 5 sows and litters were fed 70 days on corn meal, wheat middlings, and sour skim milk. The unweaned pigs were also given all of the same food they would consume at a separate trough. At 10 weeks the pigs were weaned, and the feeding continued for 7 weeks with the sows and weaned pigs separately. While suckling their pigs, 1 sow lost and 2 gained in weight. The table shows the feed required for 100 lbs. of net gain with sows and pigs before and after weaning:

Feed for 100 lbs. gain by sows and pigs before and after weaning

	Meal	Milk	Meal equivalent
	Lbs.	Lbs.	Lbs.
By sows and pigs 10 weeks before weaning	237	475	316
By pigs only, 7 weeks after weaning	288	576	384
By sows only, 7 weeks after weaning	710	1,420	947

It is shown that 237 lbs. of grain, together with 475 lbs. of separator skim milk, produced 100 lbs. of combined net gain with sows and their unweaned pigs. Reckoning 6 lbs. of skim milk equal to 1 of the mixed meal, it is shown that 316 lbs. of meal equivalent produced 100 lbs. net gain with sows and their unweaned pigs. For the 7 weeks following weaning the pigs required 384 lbs. of meal equivalent, or 22 per ct. more

[1] Wis. Rpt. 1897.

feed, for 100 lbs. of gain than before weaning. It thus appears that young, unweaned pigs are fed more economically thru the sow than after weaning. The table shows that, after their pigs were weaned, the sows required the surprisingly large amount of 947 lbs. of meal equivalent to make good each 100 lbs. of flesh lost while suckling their pigs. The prudent stockman always feeds both sows and pigs liberally before weaning, realizing that the sows should not be allowed to grow thin thru scant feeding.

914. Gain of young pigs.—To show the rate of gain by young pigs before and after weaning, the following table is taken from a study by the senior author at the Wisconsin Station,[1a] the data covering 70 days before and 49 days after weaning:

Weight of a litter of pigs at birth and gains before and after weaning

Date	Days from birth	Wt. of sow	Weight of pigs							
			No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
Before weaning										
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
May 24	......	332	......	......	......	......	......	......	......	......
May 25	0	......	3.6	3.2	3.3	3.2	3.4	3.2	2.8	1.9
May 31	7	290	7.1	5.1	5.9	6.4	6.3	5.8	4.8	3.0
June 7	14	285	10.7	7.7	9.9	9.4	9.5	9.2	7.5	5.1
June 14	21	277	19.0	11.5	13.5	13.5	12.5	12.5	10.8	7.6
June 21	28	278	19.4	14.5	17.4	17.8	15.6	16.0	14.1	10.4
June 28	35	280	24.2	16.4	22.2	23.1	20.6	20.9	18.2	14.4
July 5	42	293	28.0	18.7	25.5	26.5	23.5	24.2	22.0	16.5
July 12	49	280	32.5	19.0	30.0	32.5	29.0	29.5	26.0	21.0
July 19	56	278	40.5	22.5	37.0	43.5	38.0	38.0	35.5	26.5
July 26	63	268	47.0	24.5	44.0	51.0	45.5	45.0	42.5	31.0
August 2	70	261	50.5	25.0	50.0	60.5	50.0	51.0	47.0	37.5
Gain	......	—29	46.9	21.8	46.7	57.3	46.6	47.8	44.2	35.6
After weaning										
August 2	0	......	50.5	25.0	50.0	60.5	50.0	51.0	47.5	37.5
August 9	7	......	53.0	25.0	57.5	68.0	57.5	55.0	54.5	44.0
August 16	14	......	57.0	27.5	63.5	75.0	61.0	59.0	61.0	50.0
August 23	21	......	62.5	33.5	72.5	86.5	67.0	69.0	72.0	56.0
September 6	35	......	69.0	43.0	84.0	101.0	80.0	76.0	79.0	64.0
September 13	42	......	77.5	48.0	94.0	105.0	86.0	88.0	88.0	74.0
September 20	49	......	85.5	56.0	104.0	114.0	92.0	93.0	93.0	82.0
Gain	......	......	35.0	31.0	54.0	53.5	42.0	42.0	45.5	44.5

It will be seen that the sow lost 29 lbs. in weight while suckling her pigs, which gained from 21.8 to 57.3 lbs. each in 10 weeks between farrowing and weaning. For the 7 weeks succeeding weaning the individual gains ranged from 31 to 54 lbs. It is possible for a suckling pig to weigh 70 lbs. when 70 days old, and sometimes, tho rarely, it may exceed that high figure.

[1a] Wis. Rpt. 1890.

915. Maintenance requirement of the pig.—At the Wisconsin Station[2] Dietrich gradually reduced the feed of four 50-lb. pigs getting corn meal, wheat middlings, and skim milk during 2 weeks until they were neither gaining nor losing in weight. They were held on this allowance for 7 days to confirm the figures and then gradually brought back to full feed again. When the pigs averaged 100 lbs. the process was repeated, with the results shown in the table:

Daily maintenance requirement of pigs at different weights

	Average ration		Digestible nutrients per 100 lbs. live weight	
	Concentrates	Skim milk	Crude protein	Total
	Lbs.	Lbs.	Lbs.	Lbs.
When pig weighed 50 lbs.	0.3	1.2	0.12	0.60
When pig weighed 100 lbs.	0.8	1.6	0.12	0.70
When pig weighed 150 lbs.	1.6	1.6	0.13	0.84
When pig weighed 200 lbs.	2.0	...	0.10	0.72

The table shows that a 50-lb. pig maintained its weight on a ration of but 0.3 lb. of concentrates (corn and middlings) and 1.2 lbs. skim milk, which furnished 0.12 lb. digestible crude protein and 0.60 lb. total digestible nutrients per 100 lbs. live weight. The amount of feed eaten daily per pig increased as the pigs grew heavier, but there was no marked change in the requirements per 100 lbs. live weight. In these and also in later experiments at the Illinois Station[3] Dietrich found that if the ration was reduced after the animal was apparently receiving only enough feed to maintain its weight it would lose in weight for a period and then often be able to maintain itself on the reduced ration or even gain in weight, due to a better utilization of the feed. It has already been pointed out that steers fed scanty rations are likewise able to utilize their feed more efficiently than when liberally fed. (**82**)

Dietrich found that pigs could be maintained on 0.10 lb. digestible crude protein and 0.42 to 0.57 lb. total digestible nutrients per 100 lbs. live weight. This is 4.2 to 5.7 lbs. total digestible nutrients per 1,000 lbs. live weight, somewhat less than the amount required by the dairy cow or the steer, as is shown in Appendix Table V. This is probably due to the fact, previously pointed out (**91**), that maintenance requirements depend upon body surface, and since the pig is built more compactly than the steer or cow, he has less body surface per 100 lbs. live weight.

916. Utilization of feed by the pig.—In the trial reported in the preceding article, after each maintenance period the pigs were gradually returned to full feed, which was continued until the next maintenance period. The following table shows the gains made during these intermediate periods, together with the percentage of the feed which was required for maintenance and used for making gain.

[2]Wis. Rpt. 1899. [3]Ill. Bul. 163.

Use made by the pig of the feed consumed

	Av. daily gain	Percentage of food used For maintenance	For gain
	Lbs.	Per ct.	Per ct.
When pig weighed 50 lbs.	0.93	18	82
When pig weighed 100 lbs.	1.66	25	75
When pig weighed 150 lbs.	1.85	27	73
When pig weighed 200 lbs.	1.22	36	64

The table shows that the 50-lb. pig, when gaining nearly 1 lb. a day, used only 18 per ct. of its feed for the support of the body, leaving 82 per ct. of all it consumed for gain in body weight. As the pig increases in weight, as has already been pointed out, it consumes less feed per 100 lbs. live weight, and hence after the maintenance requirements are met has a smaller percentage of its feed left for gain. (**913**)

917. Maintenance of the sow.—At the Wisconsin Station[4] Davies recorded the feed eaten by a 394-lb. Berkshire sow and her 7 suckling pigs for 10 weeks between farrowing and weaning, obtaining the following results:

Feed required to maintain the brood sow

	Concentrates	Skim milk
	Lbs.	Lbs.
Feed (½ corn, ½ wheat middlings) consumed by sow	660	1,381
Calculated amount needed to maintain sow alone	242	484
Feed eaten by sow that went to nourish her pigs	418	897
Additional feed given to pigs	100	313
Total	518	1,210
Feed given sow and pigs for 100 lbs. gain by pigs	146	339
Feed required to maintain sow 1 day	3.5	6.9

Davies estimates that concentrates equivalent to 1 per ct. of the weight of the sow supported her for 1 day, and that about one-third of what she ate went for the support of her own body, while two-thirds was used in elaborating milk for her young. It required but 146 lbs. of grain and 336 lbs. of skim milk fed to sow and pigs for 100 lbs. of gain by the pigs—an exceedingly small allowance.

Faville of the Wyoming Station[5] found that brood sows weighing 314 lbs. at the beginning of the trial and 376 lbs. at the close made average daily gains of 0.4 lb. on a daily allowance of 4.6 lbs. of concentrates (2 parts corn and 1 part mill feed). This ration supplied only 57 per ct. of the nutrients called for by the Wolff-Lehmann standard.

918. Nutrient requirements of swine.—Since pigs are now commonly fattened for market before maturity, they are growing rapidly as well as storing fat in their bodies. Consequently their ration should supply ample protein and mineral matter for normal growth. The requirements

[4]Wis. Rpt. 1904. [5]Wyo. Bul. 96.

of pigs of various ages, as shown in studies by the junior author of the numerous trials at American experiment stations, are set forth in the Modified Wolff-Lehmann standards. (**Appendix Table V**)

The other farm animals eat large quantities of hay, which is relatively high in mineral matter, including calcium (lime), compared with the cereal grains. Except when on pasture, pigs, on the other hand, are fed chiefly on the cereal grains, not being fitted to utilize much dry roughage. Since all the cereals, especially corn, of which pigs are unusually fond, are low in calcium, there is much greater danger than with other animals that they will not obtain sufficient calcium for normal growth of skeleton and body tissues. When rations are fed which do not contain ample calcium it should be supplied in the form of ground limestone, bone ash, or ground rock phosphate. When the ration furnishes sufficient protein to meet the standards, it will also supply sufficient phosphorus for rapid growth, since the common feeds which are rich in protein are likewise high in phosphorus. (**119**)

919. Effect of adding calcium to the ration.—The trials reviewed in a preceding chapter (**135-7**) show clearly that when pigs are fed corn alone they develop weak skeletons and fail to make normal growth. This is both because corn is low in protein and because it is low in mineral matter, especially calcium. To determine the effect upon the strength of the skeleton of adding various supplements to corn, during each of 2 years Burnett fed 4 lots, each of four 79-lb. pigs, the rations shown in the table for 137 days at the Nebraska Station.[6] The breaking strength of the right and left femur, tibia, humerus, radius, and ulna of the legs of each pig was determined at the close of the trial. During the first 5 weeks of the first trial and the first 12 weeks of the second all lots were on alfalfa pasture.

Ground bone and tankage as supplements to corn

Average ration			Daily gain Lbs.	Concentrates for 100 lbs. gain Lbs.	Av. breaking strength of bones Lbs.
Lot I,	Corn, 5.0 lbs.		1.0	511	303
Lot II,	Ground bone, 0.5 lb.	Corn, 4.5 lbs.	1.0	507	575
Lot III,	Shorts, 1.3 lbs.	Corn, 3.7 lbs.	1.0	491	354
Lot IV,	Tankage, 0.5 lb.	Corn, 4.5 lbs.	1.1	456	497

Due to the alfalfa pasture during the first part of the trial, the lot on corn alone made satisfactory gains. However, Lot II, receiving ground bone in addition to corn, had much stronger bones. The skeleton was also greatly strengthened by the addition of tankage, which contains considerable calcium, and to a small degree by the addition of shorts. As shown later (**1013**), it is important that the calcium supply in the ration of the brood sow be ample.

920. Grinding grain.—At the Wisconsin Station[7] during each of 10 consecutive winters the senior author, at first alone and later with Otis,

[6] Nebr. Bul. 107.

[7] Wis. Rpt. 1906.

fed ground corn, in comparison with shelled corn, to fattening pigs averaging 175 lbs. in weight at the beginning of the trials, during periods ranging from 63 to 98 days each. Iowa No. 3, year-old shelled corn was used, part of which was ground in a buhrstone mill to the usual fineness, while part was fed unground, as shelled corn. Since pigs do not thrive on corn alone, in all cases the ration was made up of one-third wheat middlings and two-thirds ground or shelled corn. The mixed ground corn and middlings were fed wet with a small quantity of water, while the shelled corn was fed dry and alone, the middlings having first been fed as a slop. Salt and wood ashes were supplied at all times to both lots. The results of the 18 trials are summarized in the following table:

Summary of 10 winters' feeding ground corn and shelled corn

Feed given	Total feed given: Whole corn	Total feed given: Corn meal	Total feed given: Wheat middlings	Total gain	Feed for 100 lbs. gain
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
140 pigs fed shelled corn and wheat middlings...........	46,736	......	22,590	13,828	501
140 pigs fed ground corn and wheat middlings...........	......	50,647	24,189	15,891	471

In 11 out of 18 trials the saving from grinding corn ranged from 2.5 to 18.5 per ct., and in 7 cases there was a loss by grinding, ranging from 1.1 to 11.1 per ct. On the average it required 501 lbs. of whole corn and wheat middlings for 100 lbs. of gain, and only 471 lbs. of ground corn and middlings, a saving of 6 per ct. This means that with corn worth 50 cts. per bushel there was a saving of 3 cts. on each bushel by grinding, allowing nothing for labor or expense. It was observed that the pigs getting ground corn ate more feed in a given time and gained more rapidly than did those getting shelled corn, which fact no doubt explains the general impression among farmers that pigs do better on ground corn than on shelled.

Rommel,[7a] summarizing 9 trials at 5 stations where whole or ground grains—peas, wheat, rye, oats, and barley—were fed, either dry or soaked, to fattening pigs, found it required approximately 473 lbs. of whole grain or 415 lbs. of ground grain to produce 100 lbs. of gain—a saving of 12 per ct. by grinding. We may then conclude that it will usually pay to grind the small grains for pigs.

921. Effect of preparing corn for pigs.—To study the benefits of preparing corn for pigs of various ages, King conducted trials at the Indiana Station[8] with a total of 140 pigs. Similar lots of pigs were fed either ear corn, shelled corn, or ground corn, the corn being supplemented with tankage and wheat shorts. Some lots were placed on experiment when the pigs weighed about 50 lbs., others at 85 lbs., and still others at 100 lbs., at 150 to 160 lbs., and at 210 to 220 lbs., respectively. The ear

[7a] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 47.
[8] Proc. Amer. Soc. Anim. Prod., 1913, pp. 22-31.

Effect of preparing corn for pigs of different weights

Preparation of corn	No. of pigs	Initial weight	Daily gain	Average ration			Feed for 100 lbs. gain*
				Corn	Shorts	Tankage	
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
First month							
Ear corn......	16	54	0.63	1.39	0.72	0.25	376
Shelled corn...	16	54	0.66	1.38	0.72	0.25	357
Ground corn...	16	54	0.64	1.38	0.72	0.25	370
Second month							
Ear corn......	16	73	0.89	2.33	0.75	0.25	374
Shelled corn. .	16	74	0.84	2.18	0.75	0.25	378
Ground corn...	16	73	0.84	2.25	0.75	0.25	388
Third month							
Ear corn......	43	108	0.96	3.35	0.25	0.27	404
Shelled corn...	42	106	0.92	3.32	0.26	0.28	417
Ground corn...	43	107	1.00	3.47	0.25	0.27	399
Fourth month							
Ear corn......	51	140	1.14	4.44	0.01	0.34	422
Shelled corn...	50	139	1.14	4.51	0.01	0.34	428
Ground corn...	51	141	1.23	4.65	0.01	0.34	408
Fifth month							
Ear corn.	58	178	1.21	5.21	....	0.35	460
Shelled corn...	58	178	1.20	5.29	....	0.34	468
Ground corn...	58	182	1.36	5.56	....	0.35	434
Sixth month							
Ear corn......	64	219	1.44	6.05	....	0.36	445
Shelled corn...	53	217	1.46	6.30	....	0.37	455
Ground corn...	64	226	1.58	6.43	....	0.36	431

* Ear corn reduced to shelled corn basis.

corn and shelled corn were fed dry and the ground corn was wet enough so that it would not be thrown out of the trough by the pigs while eating. In the above table the results are arranged by months, starting with the pigs weighing 54 lbs.

The table shows that during the first and second months there was no appreciable benefit from shelling corn or from grinding it. In the third month the pigs fed ground corn began to make slightly larger gains, and required a little less feed for 100 lbs. gain. When the pigs reached a weight of 140 lbs. the difference became slightly more marked. During each of the last 3 months the pigs fed ground corn ate more feed, made slightly more rapid gains, and required less feed for 100 lbs. gain. For these months the saving by grinding, however, was not large, amounting to only 4.1 per ct. on the average over ear corn. Ear corn gave better results than shelled corn.

The slightly more rapid and more economical gains of the older pigs on ground corn were probably due to the fact that as pigs mature and fatten they masticate corn less thoroly. This is shown by digestion experiments conducted by Evvard at the Iowa Station[9] with 60-lb. and 200-lb. pigs, the results of which are summarized in the table:

[9] Information to the authors.

Percentage of dry matter digested with corn fed in various forms

	By 60-lb. pigs Per. ct.	By 200-lb. pigs Per ct.
Ear corn (not including cob)	88.8	85.4
Dry shelled corn	88.0	86.5
Soaked shelled corn	87.2	85.4
Dry ground corn	87.2	87.2
Soaked ground corn	85.9	88.4

The young pigs digested corn when fed as ear corn or dry shelled corn fully as well as when the dry ground corn was fed. With young pigs soaked ground corn gave the poorest results. With the 200-lb. pigs, on the other hand, grinding increased the percentage digested. Other trials at the Iowa Station[10] show that for older pigs as large and economical gains are made when soaked shelled corn is fed as when ground corn is used. Corn should be soaked for about 12 hours and must not be allowed to become stale.

From these trials we may conclude that for young pigs there is no appreciable advantage in shelling, grinding, or soaking corn. Pigs weighing 150 lbs. or over may make slightly more rapid gains on soaked or ground corn and require somewhat less feed for 100 lbs. gain. Whether this saving, which will average 4 to 6 per ct., will cover the cost of preparation must be decided by the feeder.

922. Cooking feed.—The early agricultural authorities uniformly and strongly advocated cooking feed for swine. The first definite results in opposition came from the Maine Agricultural College[11] in 1876, which reported that as the average of 9 years of continuous experimentation it had found that 89.9 lbs. of raw corn meal was as valuable for putting gains on fattening pigs as was 100 lbs. of corn meal that had been cooked. In not a single trial did a given weight of corn meal on being cooked by steam prove as satisfactory as the same weight of uncooked meal. These results were so at variance with popular opinion that the matter was soon tried out at a number of stations, some of the findings of which are as follows:

Results of feeding cooked and uncooked grain to fattening pigs

Station reporting	No. of trials	Kind of feed	How prepared	Feed for 100 lbs. gain	
				Cooked	Uncooked
				Lbs.	Lbs.
Wisconsin*	4	Ground barley	Steamed	628	589
Wisconsin*	2	Ground corn	Steamed	517	463
Wisconsin*	2	Whole corn, shorts	Steamed	564	484
Wisconsin*	3	Corn meal, shorts	Steamed	597	574
Ontario College†	2	Peas	Steamed	475	360
Kansas Agr. College‡	1	Whole corn	Steamed	750	630
Iowa Agr. College §	1	Shelled corn	Not stated	538	443
Iowa Agr. College §	1	Ground corn	Not stated	562	445
Ottawa‖	1	Ground peas, barley, rye	Steamed	417	425

* 4th An. Rpt. †2d An. Rpt. ‡Rpt. 1885. §Coburn, Swine in America. ‖Rpt. 1891.

[10] Iowa Bul. 106. [11] An. Rpt. Trustees Me. State Col. Agr., 1876.

The trials above reported, which are but a fraction of all that have been made in this country, show that in most cases there is an actual loss of food value by cooking the various grains for fattening swine. Some few feeds, such as potatoes, are improved by cooking, but as a rule there is no gain and usually a loss by such operation. (**425, 427, 429**) From trials at the North Platte, Nebraska, Substation[12] in which the value of stewing alfalfa hay for pigs was tested, Snyder concludes that the farmer is not warranted in going to much, if any, expense in thus preparing the hay. (**426**)

923. Wetting or soaking feed.—Rommel,[13] studying all the trials at the various stations in which feed was either wet or soaked with water before feeding, found a difference of only 2 per ct. in favor of soaking or wetting. We have seen in a preceding article (**921**) that it may be advisable to soak shelled corn for large pigs, while this does not noticeably increase its value for young animals. Any grain so hard as to injure the mouths of the pigs during mastication should always be soaked if it can not be ground or rolled. This is especially necessary with such small, hard grains as wheat and rye. In a trial at the Kansas Station[14] Kinzer and Wheeler found no advantage from soaking alfalfa meal and ground corn for fattening pigs. In trials at the Indiana Station[15] Plumb and Van Norman, when feeding corn meal or hominy feed with shorts to pigs, found it made no difference whether 1 or 3 lbs. of water per pound of meal was used to form the slop. Good and Smith of the Kentucky Station[16] state that when dry ground wheat is fed to pigs it often gums up in the mouth, forming a pasty mass which is difficult to masticate and swallow. Feeding the wheat as a thin slop largely overcomes this trouble. In severe winter weather slop should be warmed for pigs housed in cold quarters.

924. Light vs. heavy feeding.—In experiments at the Copenhagen (Denmark) Station[17] with sixty 35-lb. pigs, the influence of intensity of feeding on gain was especially studied. The following results were secured in trials lasting 120 and 210 days, respectively, the feeds used being barley, buttermilk, skim milk, and whey:

Results from feeding heavy and light rations

Character of feeding	Grain fed daily Lbs.	Av. gain per day Lbs.	Grain for 100 lbs. gain Lbs.
Light	3.61	0.92	391
Medium	4.23	1.07	397
Heavy	4.51	1.12	404

These results indicate a tendency toward a poorer utilization of the food in the heavier feeding, tho the difference is slight.

[12] Nebr. Bul. 147.
[13] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 47.
[14] Kan. Bul. 192. [15] Ind. Bul. 86. [16] Ky. Bul. 190.
[17] Copenhagen (Denmark) Rpt. 30, 1895.

925. Self feeders for swine.—Evvard of the Iowa Station[18] has conducted numerous trials with self feeders for various classes of swine. His results show that this method of feeding is well adapted to the quick fattening of well-grown shotes, for fattening old sows, and for growing, fattening shotes where it is desired to feed them an unlimited grain allowance. The self feeder should not be used when rapid gains are not wanted, for instance, where it is desired to force pigs to make the maximum use of pasturage by limiting the grain allowance. It should not be used for pregnant sows except early in pregnancy or unless bulky feed, of which ground alfalfa is the best under corn-belt conditions, is mixed with the grain. By decreasing or increasing the proportion of corn the gilts or sows may be kept in the proper condition.

To compare the rate and economy of gains when pigs were self-fed and hand-fed, Evvard fed 3 lots, each of 5 spring pigs, from weaning until they weighed 250 lbs. on the feeds shown in the table. The pigs were grazed on alfalfa pasture during the summer and finished in the dry lot.

Self feeder for pigs on alfalfa pasture

Average concentrate allowance	Time to reach 250 lbs. Days	Daily gain Lbs.	Concentrates for 100 lbs. gain* Lbs.
Lot I			
Ear corn, hand-fed, 3.8 lbs.*			
Meat meal, hand-fed, 0.28 lb.	206	1.06	385
Lot II			
Ear corn, hand-fed, 3.6 lbs.*			
Meat meal, self-fed, 0.39 lb.	206	1.07	373
Lot III			
Shelled corn, self-fed, 4.1 lbs.			
Meat meal, self-fed, 0.33 lb.	180	1.22	364

*Ear corn reduced to shelled corn basis.

Lot III, getting shelled corn and meat meal in separate feeders, made the largest gains, reaching 250 lbs. in 180 days, and also required the least concentrates in addition to pasture for 100 lbs. gain. A lot of 241-lb. yearling sows self-fed in a dry lot on shelled corn gained 2.6 lbs. per head daily, requiring 417 lbs. of corn for 100 lbs. of gain. Another lot hand-fed on shelled corn gained 0.3 lb. less per head daily, and required 436 lbs. of corn for 100 lbs. of gain.

The large gains which may be secured with growing pigs self-fed in dry lots on corn and suitable supplements are shown in another trial by Evvard in which 3 lots, each of five 45-lb. pigs, were allowed access to the following feeds in separate self feeders for 162 days. A fourth lot on alfalfa pasture was supplied shelled corn in addition by means of a self feeder and finished in a dry lot on shelled corn and meat meal in self feeders for 22 days after the pasture was gone. Salt was supplied each lot in a self feeder, and in addition ground limestone and charcoal were furnished the pigs in the dry lots.

[18]Proc. Amer. Soc. Anim. Prod., 1914; Corn Belt Meat Producers' Assoc., Rpt. 1914.

Value of self feeder for growing, fattening pigs

Average ration		Daily gain Lbs.	Concentrates per 100 lbs. gain Lbs.
Lot I			
Shelled corn, 5.4 lbs.			
Oats, 0.10 lb.	Meat meal, 0.46 lb.	1.5	399
Lot II			
Shelled corn, 6.0 lbs.	Linseed meal, 0.10 lb.		
Oats, 0.08 lb.	Meat meal, 0.40 lb.	1.6	417
Lot III			
Shelled corn, 5.6 lbs.			
Oats, 0.04 lb.	Linseed meal, 0.02 lb.		
Middlings, 0.22 lb.	Meat meal, 0.42 lb.	1.5	418
Lot IV			
Shelled corn, 5.9 lbs.			
Alfalfa pasture	Meat meal, 0.07 lb.*	1.5	395

*Meat meal fed only while in dry lot.

All these self-fed pigs made exceedingly large and economical gains. The pigs in Lot II reached an average weight of 316 lbs. at 248 days of age, one of the pigs weighing 405 lbs., an unusual record. Evvard states that pigs allowed free access to corn and supplements, such as tankage, linseed meal, and wheat middlings, show a remarkable ability to balance their own ration. At first about 75 per ct. of the entire ration was corn and the remainder meat meal and other supplements. As the pigs grew older they widened the nutritive ratio of their ration till at the close about 99 per ct. of the feed eaten was corn. All lots showed a tendency to eat a larger proportion of oats during the first few weeks than later, finally consuming only an insignificant amount of this bulky feed as they became well fattened. Evvard points out that when pigs are not supplied with all the corn they will eat it is inadvisable to feed tankage in a self feeder, for because of hunger they will eat more meat meal than is needed to balance their ration.

926. Water required by pigs.—Dietrich,[19] who has given the subject much careful study, concludes that the proper amount of water for the pig ranges from 12 lbs. daily per 100 lbs. of animal at the time of weaning down to 4 lbs. per 100 lbs. during the fattening period. He holds that pigs do not usually drink enough water in winter, and that they should be forced to take more by giving it, warm if necessary, in their slop. He states that the total quantity of water drunk seems to be of greater importance than the manner in which it is administered. On protein-rich feeds the pig needs more water than when on starchy feeds. **(103)**

927. Salt and correctives of mineral nature.—Tho pigs require less salt than the other farm animals, they should be supplied with it regularly. In a trial by Evvard at the Iowa Station[20] pigs allowed free access to salt made better gains than those receiving no salt or others getting allowances of one-sixty-fourth, one-thirty-second, or one-sixteenth ounce

[19] Swine, p. 156.

[20] Information to the authors.

per head daily. Salt may be supplied in a trough or a small self feeder. If pigs have not had free access to salt they may at first overeat.

Pigs, especially those kept in confinement, often show a strong craving for seemingly unnatural substances—charcoal, ashes, mortar, soft coal, rotten wood, soft brick, and many others being greedily devoured when offered. Such cravings should be satisfied by supplying such materials as charcoal, air-slaked lime or ground limestone, wood ashes, bone meal or ground rock phosphate, and copperas, with or without salt. A mixture of correctives may be placed before the pigs or they may be offered in separate compartments of a covered trough or of a self feeder.

928. Proprietary stock foods.—At the Ottawa Experimental Farms[21] Grisdale fed groups of 4 pigs, ranging in weight from 45 to 75 lbs. each, for 90 days to test the value of certain proprietary stock foods when added to a mixture of half shorts and half mixed ground grains—peas, oats, and barley. The results of the trial are shown below:

Value of proprietary stock foods in pork production

Allowance of stock food or supplement	Meal per head daily	Av. daily gain	Feed for 100 lbs. gain		Cost of 100 lbs. gain
			Meal	Other feed	
	Lbs.	Lbs.	Lbs.	Lbs.	Dollars
I, Meal alone	5.2	1.2	438	...	4.38
II, Anglo-Saxon stock food, 0.22 lb.	4.3	1.0	432	22	6.52
III, International stock food, 0.12 lb.	4.0	0.9	437	12	6.17
IV, Herbageum, 0.13 lb.	4.9	1.3	393	10	5.15
V, Sour skim milk, 3.7 lbs.	3.5	1.2	295	309	3.42
VI, Clover and rape pasture	4.8	1.2	421	Pasture	4.21

Of those receiving stock food, only Lot IV, fed Herbageum, made larger gains than Lot I, fed a straight meal ration. Valuing the mixed meal at $1, skim milk at 15 cents per 100 lbs., and the stock foods at market prices, all the lots receiving stock food made more expensive gains than Lot I. Skim milk at 15 cents per 100 lbs. lowered the gain-cost materially, and clover and rape pasture to a less degree. In this trial the stock food was added to a palatable, well-balanced ration of mixed grains.

In trials at the Iowa Station[22] with International, Iowa, and Standard stock foods Michaels and Kennedy found that the stock foods when added to corn alone had no beneficial effect on digestion and that a bushel of corn produced as much or more pork when fed alone as when stock foods were added to it. (289)

At the Kansas Station[23] Kinzer and Wheeler fed International, Pratt's, and Hercules stock foods with corn to 170-lb. pigs in comparison with others fed corn alone and still others fed corn and tankage, or corn, tankage, and wheat shorts. The pigs fed corn and stock food made but slightly larger gains than those fed corn alone, while those fed corn and tankage, or corn, tankage, and shorts gained over twice as much as those fed corn

[21] Ottawa Expt. Farms Rpt. 1904. [22] Iowa Bul. 113. [23] Kan. Bul. 192.

alone. The wise farmer will not seek to use stock foods as a supplement to corn, but will employ such protein-rich feeds as skim milk, tankage, wheat middlings, and linseed meal.

929. Winter vs. summer feeding.—The Copenhagen (Denmark) Station[24] has compiled the results of 199 trials conducted at that station with about 2,500 pigs, so as to compare the relative economy of gains by pigs in summer and winter. In the following table, which summarizes the results of these trials, all the skim milk, whey, roots, etc. fed have been reduced to their grain equivalent to facilitate comparison:

Feed required to fatten Danish pigs in winter and in summer

Weight	Grain equivalent eaten per day per head		Grain equivalent for 100 lbs. gain	
	Winter	Summer	Winter	Summer
	Lbs.	Lbs.	Lbs.	Lbs.
35 to 75 lbs.*	2.66	2.65	371	346
75 to 115 lbs.	3.96	3.92	446	397
115 to 155 lbs.	5.26	5.25	516	457
Average	3.96	3.94	444	400

*Danish pound=1.1 avoirdupois lbs.

It is shown that winter-fed pigs required 444 lbs. feed for 100 lbs. gain, or 11 per ct. more than summer-fed pigs. In Denmark the summers are cool, and the winters more or less damp but not excessively cold. It is fair to hold that in the northern parts of America the difference between winter and summer feeding is somewhat greater than the Danish figures indicate, while over much of our country there is no greater difference and often no difference at all.

930. Shelter and exercise.—Even in the northern part of the corn belt where the winters are severe, inexpensive shelter is all that is necessary for swine. The requisites for healthful winter shelter are freedom from dampness, good ventilation without drafts on the animals, sunlight, reasonable warmth, and a moderate amount of dry bedding. The quarters should be located on well-drained ground and should be so arranged that they may be easily and thoroly cleaned and disinfected.

Swine may be housed in a central hog house with a number of pens or in small movable "cabins" or colony houses. Many use a combination of the 2 systems, for in the northern states the central house is well suited for winter shelter and spring farrowing, while the portable houses are particularly useful for housing pigs on pasture. At the Ottawa Station,[25] where the winters are severe, Grisdale kept lots, each of 4 to 7 pigs weighing about 70 lbs., during 60 days in winter in small board houses, such as were used for summer shelter. Other lots were kept in the well-built piggery, which afforded much greater protection. The pigs in the small houses gained 0.68 lb. per head daily, 0.02 lb. less than those kept in the piggery, and required 44 per ct. more feed for 100 lbs. gain.

[24]Copenhagen (Denmark) Station, Rpt. 30, 1895.

[25]Ottawa Expt. Farms, Rpt. 1904.

Brood sows in the small houses required only 25 per ct. more feed than those in the warmer quarters, showing that large animals can withstand severe cold better than small ones. The health of the animals was good under both conditions. Shelton of the Kansas Agricultural College[26] found that during a winter in which the temperature at 8 a. m. ranged from 31° F. to –12° F. large hogs in warm quarters required 25 per ct. less feed than those in a yard protected only by a high board fence on the north.

Tho somewhat more feed is required by pigs wintered in the small, colder houses, this is more or less offset by the low cost of the cabins and by the ease with which they may be shifted to prevent disease and parasites and to distribute the droppings of the animals. In severe weather corn stalks, horse manure, or other litter may be banked against the sides of the houses. With liberal bedding, all but the youngest pigs should then be comfortable. When litters come in severe weather a lantern hung in the cabin will furnish sufficient warmth.

For breeding stock and growing pigs ample exercise is of the utmost importance. To enforce exercise animals quartered in several cabins can be fed at a point, at some distance from the shelters, where there are troughs and a feeding floor. When snow covers the ground, paths can be broken out with a snow plow. In winter, even where the cold is severe, pigs housed in colony houses and forced to take daily exercise thrive amazingly. If a permanent hog house is used abundant exercise should be enforced at all times with breeding and stock animals.

931. Types of swine; breed tests.—The principal breeds of swine are of 2 distinct types, the lard type, of which the Poland-China, Berkshire, Chester-White, and Duroc-Jersey are the leading breeds, and the bacon type, represented by the Tamworth and Large Yorkshire breeds. The Hampshires, tho often classed as bacon hogs, really stand between the extreme bacon type and the lard type. Lard hogs, which are the type commonly raised in the United States, have compact, wide, and deep bodies. Since the hams, back, and shoulders are the most valuable parts, the packer desires a hog furnishing a maximum of these cuts. Usually being well-fattened, lard hogs yield a high percentage of dressed carcass. Formerly heavy hogs were in largest demand, but now pigs weighing 250 lbs. or less will command the highest price, if well finished.

The true bacon type is raised but little in the United States, the domestic demand for bacon being largely satisfied by the leaner pigs of the lard type. The bacon pig is raised chiefly in Denmark, Great Britain, and Canada, where corn is not the main feed for swine. Pigs of the bacon breeds are longer of body and of leg than those of the lard breeds, have less thickness and depth of body, and are lighter in the shoulder, neck, and jowl. The highest quality bacon is that made for the English market under the name of "Wiltshire side," which consists of the whole half of the dressed pig, less the head, feet, shoulder blade, neck bone, and

[26]Kan. Agr. Col., Rpt. Prof. Agr., 1883.

aitch bone. For this purpose the pigs should weigh from 160 to 200 lbs. and carry but medium fat, which should be uniformly from 1 to 1.5 inches in thickness along the back.[27]

Breed tests have been conducted at several stations to determine whether there is any difference in the economy of meat production by the different breeds. Of these the most extensive were tests at the Ontario Agricultural College[28] and the Iowa Station,[29] in which pigs of the Berkshire, Poland-China, Duroc-Jersey, Chester-White, Tamworth, and Yorkshire breeds were compared. A study of the results shows that there was no consistent and uniform difference in gains or economy of production, a breed which ranked high in some of the tests, being surpassed by other breeds in the rest of the trials. The bacon breeds made as economical gains as those of the lard type. We may conclude that there is no best breed of swine so far as rate and economy of gains are concerned. There are far greater differences between individuals of the same breed than between the different breeds. One should select the breed which seems best adapted to his conditions and suits his fancy, and then be sure to secure and to maintain vigorous, well-bred animals of that breed.

932. Razorbacks.—Carlyle of the Wisconsin Station[30] procured razorbacks or semi-wild swine, also called feral swine, from Texas and Oklahoma. In one trial 6 unmixed descendants from the original pair of razorbacks were fed in comparison with the same number of pigs obtained by crossing razorbacks on improved Berkshires or Poland-Chinas.

The razorbacks made slower gains and required more feed for a given gain than did the cross-breds. Carlyle reports that they were also fickle in appetite. At one time they would gorge themselves, and then eat sparingly, only to follow with another gorge. They seemed to thrive best with abundant pasture and bulky food. The second cross with the improved breeds produced pigs of fine form that were good feeders. None were immune from hog cholera, the original pair dying of that disease.

933. Spayed and unspayed sows.—At the Utah Station[31] Foster and Merrill secured a daily gain of 0.82 lb. with spayed sows and 0.86 lb. with unspayed sows, no difference in their appetites being noticed.

934. Barrows vs. sows.—In feeding trials mostly by the senior author at the Wisconsin Station,[32] the weights and gains of 98 sows and an equal number of barrows were as follows:

	Sows	Barrows
Av. weight at beginning of feeding period, lbs.	136	144
Av. gain per animal during feeding period, lbs.	102	107

It is shown that the barrows, weighing somewhat more than the sows, made slightly better gains. Data obtained in feeding 1,216 pigs at the

[27] Day, Productive Swine Husbandry, pp. 13–14.
[28] Ont. Agr. Col., Rpts. 1896–8.
[29] Iowa Bul. 48.
[30] Wis. Rpt. 1903.
[31] Utah Bul. 70.
[32] Wis. Rpts. 1897–1906.

Copenhagen (Denmark) Station[33] showed practically no difference between barrows and sows as to gain, shrinkage, or quality of carcass.

935. Length of intestines.—Darwin[34] states that the nature of the food supplied the pig by man has evidently changed the length of the intestines. He quotes Cuvier as reporting the total length of the intestines of the wild boar to be 9 times the body length; in the domestic boar 13.5 to 1; in the Siam boar 16 to 1. The senior author[35] measured the intestines of 39 fattened hogs and found that the large intestine varied from 13 to 16 ft., and the small intestine from 54 to 60 ft. in length. The average extreme body length of these animals was 3.5 ft. This makes the small intestine alone from 15 to 17 times the length of the body, and the large and small intestines combined about 21 times the body length. From these figures it appears that the intestines of pigs of the improved breeds are longer in proportion to the body than those given by Cuvier. This may indicate that the modern pig can digest his food more thoroly than his ancestors, and also that he can eat a larger quantity of food in a given time. (**35**)

936. Dressing percentage.—Coburn[36] gives the following concerning the percentage of dressed carcass that pigs will yield on slaughtering after being deprived of feed for 12 hours.

Yield of dressed carcass by pigs of various weights

	Dressed carcass Per ct.		Dressed carcass Per ct.
Live weight, 100 lbs	72	Live weight, 250 lbs	77
Live weight, 150 lbs	73	Live weight, 300 lbs	79
Live weight, 200 lbs	75	Live weight, 350–500 lbs	80–87

It is shown that the small, immature, unfinished pig yields the least and the large, mature fat one the greatest percentage of dressed carcass. For each 100 lbs. of live weight increase over the first 100 lbs. the yield is approximately 4 per ct. more dressed carcass. The pig leads all 4-footed farm animals in the percentage of available carcass it yields.

937. Requirements for bacon production.—Day[37] of the Ontario Agricultural College states that to produce a good Wiltshire side of bacon requires in the pig "certain definite peculiarities as to weight, condition, and conformation." The customers for this class of bacon are most fastidious, and bacon which does not come up to the standard in every particular is heavily discounted. The fat should be clear white in color, the flesh firm, and there should be a much higher percentage of lean to fat than in the carcass of the lard hog. (**931**)

According to Day, a peculiar feature of swine is their tendency to develop fat. If the very best specimens of the bacon type are fed largely

[33]Copenhagen (Denmark) Station, Rpt. 1895.
[34]Animals and Plants under Domestication.
[35]Wis. Rpt. 1889.
[36]Swine in America, p. 535.
[37]Productive Swine Husbandry, p. 13.

on corn, in a couple of generations they will show a tendency to become shorter and thicker in body. "Even under the most favorable conditions there is a tendency for the bacon type to change gradually in the direction of the fat type, unless care is exercised in selection. It is safe to say, therefore, that it is easier to increase the proportion of fat in a hog's carcass than it is to increase the proportion of lean, and that the extent to which the lean may be increased by the character of the feed is very limited and is fixed by the individuality of the animal. Further, any attempt to increase the amount of lean thru feeding must be started when the pig is very young in order to be successful." **(137)**

938. Soft pork.—In bacon production a varying number of carcasses are usually rejected by the packers after slaughter because they are too soft for the requirements of the bacon market. Olein, palmitin, and stearin are the three principal fats in the lard of the pig. Olein is liquid at ordinary temperatures, while the others are solid. Shutt of the Ottawa Experimental Farms[38] concludes that soft pork is largely due to an undue proportion of olein in the fat of the carcass. He finds that the fat of firm pork carries 68 per ct. olein or less, and that of soft pork 75 per ct. or more. Pigs fattened exclusively on corn give a lard carrying as much as 92 per ct. of olein, while an oats-peas-barley ration produces a lard with only 67 per ct. olein.

From the extensive studies of Fjord and Friis of the Copenhagen (Denmark) Station,[39] and those of Day, Grisdale, and Shutt of the Canadian Stations,[40] we learn that soft pork unsuited to the production of high quality bacon is due on the part of the animal to unthriftiness, lack of exercise, immaturity, and lack of finish, and only in a small way to the breed. Imperfect feeding, marketing before being finished, holding too long after finishing, and undue forcing—especially when immature—are other causes. In general, improper feeding stuffs and feeds improperly combined tend to produce low-quality bacon. According to Day,[41] exclusive meal feeding is one of the most common causes of softness, especially with pigs not given exercise. Of the grains in common use, corn has the greatest tendency to produce softness. This can be modified by mixing it largely with other meal, or by feeding skim milk, green feed, and roots, but its tendency to produce softness is so strong that it is undesirable for bacon pigs when fed in large amount. While corn appears to give a good quality of meat in the case of the lard hog, it must be remembered that the bacon hog is marketed at lighter weights and in thinner condition than the lard hog, which may possibly explain why corn is unsatisfactory for feeding bacon hogs. It is possible also that the difference in the methods of curing the flesh may have an influence. Beans seem to have a more marked effect than corn in pro-

[38] Ottawa Expt. Farms, Bul. 38.

[39] Copenhagen (Denmark) Rpts. 1884, et seq.

[40] Rpts. and Buls. Ont. and Ottawa Expt. Stations, 1890–96.

[41] Productive Swine Husbandry, pp. 133–5.

ducing soft pork and should not be used for finishing bacon hogs. Soybeans and peanuts also tend to produce a soft, oily pork. Barley ranks first for producing the highest grade of bacon, while oats and peas follow. Skim milk and whey in combination with the cereal grains, including corn, make a solid flesh that is particularly desirable. Rape, roots, and clover are helpful, but these and other succulent feeds should be judiciously used. Pigs that have been properly fed and have had freedom until they weigh 100 lbs., if in thin condition, may be finished on almost any of the common meal mixtures and produce fine bacon. They should be fed slightly less than the full ration.

Kennedy states[42] that the following rations are used by the Danes, who excel in the production of bacon: "Ground barley, cooked potatoes, and skim milk; shorts and skim milk; 2 parts shorts, 2 parts ground barley, 1 part corn meal, and skim milk; 2 parts ground barley, 1 part wheat bran, 1 part ground rye, and skim milk; 2 parts ground barley, 1 part ground oats, 1 part corn meal, and skim milk. Corn meal is fed with care, especially during warm weather; when fed in small quantities with barley, shorts, oats, and bran, combined with a liberal allowance of skim milk, there are no bad results. Some good feeders use corn meal to the extent of one-third or one-half of the grain ration during the first 3 or 4 months and then omit it and finish with oats or similar feed. Feeders are sometimes compelled to use corn on account of the low price of bacon. Ground rye to the extent of about one-third of the ration gives good results, but rye shorts are not satisfactory and are only used in small quantities. The best feeds are ground barley, crushed oats, and wheat shorts. Roots are fed during winter and soiling crops during summer."

[42] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 77.

CHAPTER XXXIV

FEEDS FOR SWINE

I. Carbonaceous Concentrates

The digestive organs of the pig, with their contents, comprise but 7.5 per ct. and those of the ox over 14 per ct. of the total weight of the body. (35) The horse, ox, and sheep are normally herbivorous, living on the finer and more delicate portions of plants and their seeds, while the omnivorous pig feeds not only on the tender leaves, stems, roots, and seeds, but on animal matter as well. Because of the limited capacity of the stomach and the nature of its digestive apparatus the pig requires food that is more concentrated and digestible and less woody than that of the other large farm animals. Not only is the pig an omnivorous feeder, but in nature it lives close to the earth, gathering some of its food from beneath the surface and swallowing considerable earthy matter in doing so. The intelligent swine feeder bears all such facts in mind in feeding his herd.

939. Indian corn.—This imperial fattening grain is the common hog feed in the great pork-producing districts of America. Corn is low in protein compared with its wealth of carbohydrates and fat, and is also deficient in mineral matter. (201) Hence, even for fattening well-grown pigs, much larger and more economical gains are secured when this grain is properly supplemented by feeds rich in protein and mineral matter, especially calcium, or lime. This is clearly shown in the following table, which summarizes the results of 32 trials at various stations, averaging 82 days, in each of which one lot of pigs was fed corn alone and another lot corn and a protein-rich concentrate, such as tankage, wheat middlings, linseed meal, pea meal, or soybean meal.

Corn alone vs. corn and nitrogenous supplement for pigs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Lbs.
Lot I, total of 180 pigs			
Corn, 4.8 lbs.	115	0.9	602
Lot II, total of 187 pigs			
Corn, 4.3 lbs. Supplement, 1.4 lbs.	117	1.3	441

Altho most of these pigs were well grown when placed on trial, averaging over 100 lbs. in weight, Lot II, fed corn and a nitrogenous supplement, made over 40 per ct. larger gains and required 27 per ct. less feed for 100 lbs. gain. Had the pigs been younger at the beginning of the trials the results would have been even more striking. These trials show that no one can afford to feed corn alone to growing, fattening pigs. Corn alone gives better results for fattening old sows, but even here the use of a supplement is advisable. For brood sows it is highly important that feeds rich in protein and lime be supplied with corn. Many recommend that not over one-third to one-half the ration of the brood sow should consist of corn, but in the corn belt good results have been secured with corn and only enough nitrogenous supplement to balance the ration, providing the allowance of corn was so restricted that the sows did not become too fat. (**1013**)

In the corn belt most of the corn is fed on the cob, a commendable practice since it involves the least labor by the feeder and is satisfactory to the animals. (**921**) Where early fall feeding is desirable, corn in the roasting-ear stage may be supplied, stalks and all, but in limited quantity at first, for if much is eaten digestive derangements follow. As the kernels harden, the corn may be more liberally supplied. Pigs that have grazed on clover, alfalfa, or other pasture incur the least risk from new corn. Coburn[1] quotes Atkinson as stating that a given area of standing corn will go 3 times as far after it begins to dent as it will if fed off when in the roasting-ear stage. (**23**) The Virginia Station[2] found that pigs fed new ear corn made as good gains as others fed old corn.

940. Soft corn.—Coburn[3] states that soft corn is considered excellent for swine and especially for young pigs, many breeders believing they can obtain better gains from soft than from sound, hard corn. As soft corn contains less starch than mature corn, it is advisable to feed some old corn for finishing. Soft corn may be used during cold weather without danger, but should not be carried over into the warm season, as it will ferment and thereby become unfit for use. (**205**)

941. Corn meal; corn-and-cob meal.—The trials reviewed in the preceding chapter (**920-1**) show that there is no appreciable advantage in grinding corn for pigs under 150 lbs. in weight, and that for older pigs the saving of corn thru such preparation is but slight. The trials of Kennedy and Robbins at the Iowa Station[4] show that the labor involved in grinding ear corn to corn-and-cob meal is more than wasted, the pigs making larger and more economical gains on the ear corn. This seems reasonable for the pig has a digestive tract that can at best but poorly utilize a hard, fibrous material such as the corn cob, even after it is ground. Where the pig's food is limited in quantity the cob particles may be useful in distending the digestive tract. Even in such cases the feeder should supply woody matter of better character, such as clover and alfalfa hay furnish. (**208, 921**)

942. Hogging down corn.—In the corn belt many farmers turn pigs into fields of standing corn, in which rape or other supplemental crops have usually been sown, and allow them to do their own harvesting. This system, called "hogging down," was compared with feeding pigs ear corn

[1] Swine in America, p. 287.
[2] Va. Bul. 167.
[3] Swine in America, p. 276.
[4] Iowa Bul. 106.

in dry lots by Gaumnitz, Wilson, and Bassett in 2 trials at the Minnesota Station[5] and by Evvard in 1 trial at the Iowa Station,[6] with the results summarized in the table. In the Minnesota trials rape and in the Iowa trial rye was sown in the corn field at the last cultivation to furnish supplemental feed. The pigs in the Minnesota trials were also fed an allowance of shorts and in the Iowa trial an allowance of tankage in addition to the corn.

Hogging down corn compared with feeding corn in yard

	No. of pigs fed	Av. length of trial	Daily gain	Concentrates for 100 lbs. gain*
		Days	Lbs.	Lbs.
Lot I, Hogging down corn	68	53	1.4	488†
Lot II, Fed ear corn in yard	31	57	1.1	546

* Corn reduced to basis of shelled corn.
† Corn consumed by pigs hogging down crop estimated.

The pigs hogging down the corn crop made larger gains and required over 10 per ct. less concentrates per 100 lbs. gain than those fed ear corn in the yard. Evvard found that of 194 men in Iowa who had had experience with hogging down corn only 1 was unfavorable to the practice. Over 70 per ct. sowed supplemental crops in the corn field, rape being by far the most popular, followed by rye, and by pumpkins. In tests at the Iowa Station[7] rape was grown in the corn field at an additional cost of only $0.40 per acre, rape and pumpkins at $1.00, rye, soybeans, or cowpeas at $3.33, field peas at $3.60, and hairy vetch at $6.00 per acre. Rape, and rape and pumpkins were the most economical supplemental crops. Evvard found that nearly half of the farmers reporting fed some nitrogenous concentrate, such as skim milk, tankage, wheat middlings, or linseed meal, in addition to the corn. Such a supplement is especially important when no supplemental crops have been grown in the corn field. Even when supplemental crops are used it is preferable to feed a small allowance of nitrogenous concentrates in addition. Spring shotes, well grown on pasture and forage crops, are generally used for hogging down. Many turn in old sows and little pigs after the shotes are removed to clean up what little corn has been left—a good practice, for it enforces an abundance of exercise. Pigs hogging down corn pick it up as closely as is usually done in husking.

It is best to confine the pigs to limited areas of the field by fencing, so that they will clean up the corn in 20, or better, 14 days. Older hogs should be confined to smaller areas than shotes, for otherwise they will knock down and waste more corn. Woven wire is used for fencing, being tied to corn stalks and further supported by posts or stakes where necessary. According to the Minnesota Station,[8] pigs weighing 125 lbs. at the beginning will clean up 1 acre of corn in the time shown in the following table:

[5]Minn. Bul. 104.
[6]Iowa Bul. 143.
[7]Iowa Bul. 143.
[8]Minn. Bul. 104.

Number of days required by pigs to clean up 1 acre of corn

	Yield, 40 bu. per acre	Yield, 50 bu. per acre	Yield, 60 bu. per acre	Yield, 70 bu. per acre
	Days	Days	Days	Days
When 20 pigs forage..	15	19	23	26
When 40 pigs forage............	8	9	11	14
When 60 pigs forage............	5	6	8	9
When 80 pigs forage............	4	5	6	7

Field feeding of corn is most successful when the weather is dry. It is not judicious to keep pigs in the fields after heavy rains, for they then waste corn and injure the land.

943. Hominy feed.—In 5 trials at the Indiana Station, averaging 86 days, Skinner and King[9] compared the value of hominy feed and corn meal for fattening pigs, when fed with either wheat shorts or tankage, obtaining the results shown in the table:

Hominy feed vs. corn for fattening pigs

Feed given	Initial weight	Daily gain	Feed for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Lot I, Hominy feed and supplement............	102	1.15	427
Lot II, Corn meal and supplement..............	102	1.03	495

The pigs fed hominy feed made slightly larger gains than those fed corn meal and required about 14 per ct. less feed for 100 lbs. gain. Similar results were secured by Eastwood in 2 trials at the Ohio Station.[10] (**213**)

944. Barley.—In Europe barley is the most esteemed cereal for the production of high quality bacon and is important in this country as a feed for pigs in the western states. The values of barley and corn when fed with wheat middlings have been compared at 3 stations in 6 trials averaging 49 days, with the results summarized in the table:

Barley vs. corn for fattening pigs

Average ration		Initial weight	Daily gain	Feed for 100 lbs. gain
		Lbs.	Lbs.	Lbs.
Lot I, total of 32 pigs *				
Ground barley, 3.4 lbs.	Middlings, 2.8 lbs..........	108	1.26	499
Lot II, total of 32 pigs *				
Ground corn, 3.4 lbs.	Middlings, 2.7 lbs.........	104	1.34	452

* Average of 2 trials by Burnett (S. D. Bul. 63), 1 by Richards and Shepperd (N. D. Bul. 84), and 3 by Smith (Minn. Bul. 22).

The pigs fed barley and middlings made slightly smaller gains than those fed corn and middlings, and required 10 per ct. more feed for 100 lbs. gain. (**226**) As barley is carbonaceous in character and is also not especially palatable to pigs, it should never be fed alone, but with palatable protein-rich feeds. Barley kernels, being small and hard, should always be ground, or better, rolled before feeding. (**920**)

945. Wheat.—Commonly wheat of good quality is too high in price to feed to stock, but in some seasons, as in 1913, when unusually low in

[9] Ind. Bul. 158.

[10] Ohio Bul. 268.

price, it may be fed with economy in place of corn. In the following table are summarized the results of 3 trials, averaging 110 days, with a total of 46 pigs, in which ground wheat and ground corn were compared when fed with tankage, and of 8 trials, averaging 99 days, with a total of 76 pigs, in which either ground wheat or ground corn was fed alone to fattening pigs:

Wheat vs. corn for fattening pigs

Average ration		Initial weight	Daily gain	Feed for 100 lbs. gain
		Lbs.	Lbs.	Lbs.
Wheat vs. corn, fed with tankage *				
Lot I, Ground wheat, 6.2 lbs.	Tankage, 0.64 lb....	104	1.54	440
Lot II, Ground corn, 5.6 lbs.	Tankage, 0.58 lb....	98	1.37	454
Wheat vs. corn, fed alone †				
Lot I, Ground wheat, 6.3 lbs.		143	1.35	472
Lot II, Ground corn, 6.1 lbs.		140	1.23	510

* Av. of 1 trial by Eastwood (Ohio Bul. 268) and 2 by Weaver (Mo. Bul. 136).
† Av. of 1 trial by Chilcott (S. D. Bul. 38), 1 by Georgeson, Otis, and Burtis (Kan. Bul. 53), 1 by Good (Ky. Bul. 175), 2 by Weaver (Mo. Bul. 136), 1 at the Ohio Station (Rpt. Kansas Bd. Agr. 1894), and 2 by the senior author (Wis. Rpts. 1894, 1895).

Both when fed with tankage and when fed alone, good quality wheat produced slightly larger gains than did corn. The pigs fed wheat and tankage required 3 per ct. and those fed wheat alone 7 per ct. less feed per 100 lbs. gain than the corn-fed pigs. In trials at the Missouri Station,[11] Weaver found no appreciable advantage from mixing wheat and corn, either when these grains were fed alone or when fed with tankage. As wheat, like corn, is low in protein, it should always be fed with some nitrogenous supplement. (**215**)

Wheat should be ground, or preferably rolled, for swine. At the Oregon Station[12] Withycombe found that grinding wheat to a meal saved 16 per ct., and crushing or rolling 22 per ct., over the whole grain. Bliss and Lee at the Nebraska Station[13] found soaked ground wheat worth 13 to 25 per ct. more than soaked whole wheat. At the North Platte, Nebraska, Substation,[14] Snyder found that compared with whole wheat fed dry the value was increased 1 per ct. by soaking, 16 per ct. by grinding, and 19 per ct. by both grinding and soaking. As it tends to form a sticky mass in the pig's mouth it may be advisable to feed ground wheat in the form of a thin slop. (**923**) Grisdale of the Ottawa Experimental Farms[15] found that from 360 lbs. to 400 lbs. of frozen wheat were required to produce 100 lbs. of gain with fattening pigs—a most favorable showing for such grain. At the Ontario Agricultural College, Day[16] found frozen wheat fully equal to good quality barley when fed with wheat middlings.

946. Oats.—At the Wisconsin Station[17] the senior author fed whole and ground oats with corn meal to 115-lb. pigs for 60 days with the following results:

[11]Mo. Bul. 136.
[12]Ore. Bul. 80.
[13]Nebr. Bul. 144.
[14]Nebr. Buls. 144, 147.
[15]Ottawa Expt. Farms, Rpt. 1908.
[16]Ontario Agr. Col., Rpt. 1908.
[17]Wis. Rpt. 1889.

Whole oats compared with ground oats

Feed	Average ration Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Lbs.
Lot I, ⅔ whole oats, ⅓ corn meal	3.8	0.68	564
Lot II, ⅓ whole oats, ⅔ corn meal	4.0	0.82	492
Lot III, ⅔ ground oats, ⅓ corn meal	4.4	1.03	429
Lot IV, ⅓ ground oats, ⅔ corn meal	5.1	1.27	402

The pigs getting whole oats ate less feed and gave poorer returns than those fed ground oats. The best returns were with a ration of one-third ground oats and two-thirds ground corn. Owing to their bulkiness, oats should not be fed as the sole grain to fattening pigs. From trials at the Ohio Station[18] Eastwood concludes that, while oats may be used satisfactorily during the first part of the fattening period when low in price, the proportion of oats in the ration should gradually be decreased and they should be omitted entirely during the last 4 or 5 weeks.

Grisdale of the Ottawa Experimental Farms[19] found that pigs fed soaked shelled corn and skim milk made 49 per ct. greater gains than those fed soaked whole oats and skim milk—a good example of the great waste which follows the wrong combination of feeding stuffs. Oats and corn, or skim milk and corn, are proper combinations, while oats and skim milk are not. Again, oats must be ground if they are to be fed in quantity to swine, especially when the pigs are young. For pigs while still quite small there is nothing more helpful than ground oats with the hulls sieved out. For breeding stock and for shotes not being fattened, there is no more useful feed than whole oats, fed by scattering thinly on the ground or on a feeding floor. (**223**)

947. Emmer.—In a trial at the Nebraska Station[20] lasting 94 days, Burnett and Snyder compared emmer meal with corn and barley meal as a feed for fattening pigs. In a second trial lasting 42 days, an allowance of half emmer and half corn meal was fed against one of corn meal only. In both trials alfalfa hay was fed to the pigs in addition to the meal:

Emmer meal compared with corn and barley meal for pigs

Daily grain allowance	Av. wt. at beginning Lbs.	Av. daily gain Lbs.	Grain for 100 lbs. gain Lbs.
First trial			
Lot I, Corn meal, 4.8 lbs	82	1.02	470
Lot II, Barley meal, 4.8 lbs	80	0.81	590
Lot III, Emmer meal, 4.8 lbs	81	0.77	618
Second trial			
Lot I, Corn meal, 7.2 lbs	160	1.53	470
Lot II, Corn meal and emmer, 6.6 lbs	146	1.35	482

In the first trial it required 148 lbs., or 31 per ct., more emmer meal than corn meal, and 5 per ct. more emmer meal than barley meal, to produce 100 lbs. of gain. In the second trial emmer meal combined with corn meal proved nearly equal to corn meal alone. For swine emmer should always be ground and fed with other feeds. (**233**)

[18] Ohio Bul. 268. [19] Ottawa Expt. Farms, Bul. 51. [20] Nebr. Bul. 99.

948. Rye.—Extensive trials by the Copenhagen (Denmark) Station[21] showed that rye meal ranks a little below corn meal and about equal to barley meal as a feed for swine. The pork from rye-fed pigs was satisfactory, especially when the ground rye was fed with other grains, milk, or whey. Rye shorts and middlings had a lower feeding value than rye meal and produced a poorer quality of pork. In 1 trial pigs fed rye meal became sick.

Snyder found at the North Platte, Nebraska, Substation[22] that 8.6 per ct. more soaked whole rye than soaked whole wheat was required for 100 lbs. gain. (**232**) Coburn[23] recommends feeding ground rye as a thin slop, since dry rye meal forms a sticky paste in the pig's throat on which he is liable to choke. (**920, 923**) Rye may be hogged down when mature by pigs; but there is more waste than in hogging down corn.

949. The grain sorghums.—Thruout the western plains states the seed of the grain sorghums is becoming of great importance for pork production. (**235-40**) These grains are similar in composition to corn, and hence should not be fed alone, but always with other feeds rich in protein, such as skim milk, tankage, wheat middlings, linseed meal, or alfalfa hay. As the seeds are small and hard the grain should be ground. Where this is not possible, it is best to feed the sorghum on the head rather than the threshed grain. This is shown in a trial by Cochel at the Kansas Station[24] in which lots, each of ten 140-lb. pigs, were fed the allowances of kafir shown in the table with 2.3 lbs. of wheat shorts and 0.4 lb. tankage per head daily for 74 days. In addition all lots had access to alfalfa hay.

Preparation of kafir for pigs

Average allowance of kafir	Daily gain	Concentrates for 100 lbs. gain	Feed cost of 100 lbs. gain
	Lbs.	Lbs.	Dollars
Lot I, Ground kafir, 4.9 lbs.	1.40	534	6.29
Lot II, Whole kafir, 5.6 lbs.	1.15	718	7.94
Lot III, Kafir heads, 6.2 lbs.	1.28	690	6.13

Lot I, fed ground kafir, made considerably larger gains than Lot II, fed whole kafir. Tho the gains of Lot III, fed kafir in the heads, were slightly smaller than of Lot I, with head kafir at $14, whole kafir at $20, and ground kafir at $22 per ton, they made the cheapest gains. (**920**)

950. Kafir, milo, and sorgho vs. corn.—To determine the relative value of kafir, milo, and sorgho, compared with corn, Waters, Kinzer, Wright, and King[25] fed 10 lots of ten 125-lb. pigs, which had been grown during the summer on alfalfa pasture and a limited amount of grain, and carried thru the fall on alfalfa hay with a little grain, the following rations at the Kansas Station:

[21]Copenhagen (Denmark) Rpts. 1887, 1890.
[22]Nebr. Bul. 147.
[23]Swine in America, p. 347.
[24]Kansas Industrialist, May 1, 1915.
[25]Kan. Bul. 192.

Kafir, milo, and sorgho vs. corn for pigs

Average ration		Initial weight	Daily gain	Feed for 100 lbs. gain: Concentrates	Hay
		Lbs.	Lbs.	Lbs.	Lbs.
With alfalfa hay, fed 80 days					
Lot I					
Ground corn, 6.6 lbs.	Alfalfa hay, 0.6 lb...	124	1.5	432	39
Lot II					
Ground milo, 6.2 lbs.	Alfalfa hay, 0.9 lb....	125	1.2	510	74
Lot III					
Ground kafir, 7.3 lbs.	Alfalfa hay, 0.9 lb...	124	1.3	520	67
Lot IV					
Ground sorgho, 5.7 lbs.	Alfalfa hay, 0.9 lb...	126	0.9	650	103
With shorts and tankage, fed 60 days					
Lot V					
Ground corn, 4.6 lbs. Shorts, 2.2 lbs.	Tankage, 0.6 lb.....	125	2.0	370	...
Lot VI					
Ground milo, 4.2 lbs. Shorts, 2.0 lbs.	Tankage, 0.5 lb. ...	124	1.7	390	...
Lot VII					
Ground kafir, 4.6 lbs. Shorts, 2.2 lbs.	Tankage, 0.6 lb.....	125	1.8	390	...
Lot VIII					
Ground sorgho, 4.6 lbs. Shorts, 2.2 lbs.	Tankage, 0.6 lb.....	125	1.7	440	...

In both trials corn produced slightly the largest gains and with less feed for 100 lbs. of gain. The difference between corn and kafir or milo was more marked when fed with alfalfa hay. When sorgho was fed considerably more feed was required for 100 lbs. gain than with kafir or milo. On account of its lack of palatability sorgho grain is not particularly desirable as a hog feed. (**241**)

951. Grain sorghums compared.—At the Kansas Station[26] Cochel fed 5 lots, each of ten 140-lb. pigs, the allowances of grain shown in the table for 74 days to compare the value of kafir, milo, feterita, kaoliang, and corn. In addition the pigs in each lot were fed 2.3 lbs. of wheat shorts and 0.4 lb. of tankage per head daily and had access to alfalfa hay.

Grain sorghums compared with corn for fattening pigs

Average allowance of grain	Daily gain	Concentrates for 100 lbs. gain
	Lbs.	Lbs.
Lot I, Ground kafir, 4.9 lbs.	1.40	534
Lot II, Ground milo, 4.9 lbs.	1.43	523
Lot III, Ground feterita, 4.9 lbs.	1.36	549
Lot IV, Ground kaoliang, 4.9 lbs.	1.31	572
Lot V, Ground corn, 4.9 lbs.	1.46	514

Both kafir and milo produced practically as large gains as corn, and with kafir only 4 per ct. and with milo but 2 per ct. more concentrates were required for 100 lbs. gain than with corn. Feterita and kaoliang were slightly lower in value than kafir and milo, tho producing satisfactory gains. In a trial by Wilson at the South Dakota Station,[27] when

[26]Kansas Industrialist, May 1, 1915. [27]S. D. Bul. 157.

fed with alfalfa hay 27 per ct. more kaoliang was required for 100 lbs. gain than corn. From these and other trials we may conclude that when ground and fed with feeds rich in protein, the value of milo or kafir is but 2 to 8 per ct. below that of corn, while the other grain sorghums are somewhat less valuable than kafir or milo.

952. Millet.—Wilson and Skinner of the South Dakota Station[28] fed hog, or broom-corn, millet meal against barley and wheat meal to lots of 2 pigs each for 84 days with the results shown in the table:

Millet meal compared with wheat and barley meal

Average ration	Av. wt. at beginning	Daily gain per head 1st period, 56 days	Daily gain per head 2d period, 28 days	Feed for 100 lbs. gain, both periods
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I, Millet meal, 6.8 lbs.	116	1.32	0.76	595
Lot II, Barley meal, 6.2 lbs.	125	1.34	1.07	495
Lot III, Wheat meal, 8.2 lbs.	168	1.75	1.51	487

For the first 8 weeks the pigs fed millet meal gave substantially as good returns as those fed barley meal, but during the next 4 weeks they made poorer gains. Combining both periods, it required about 20 per ct. more millet than barley to produce a given gain. Millet meal should never be fed alone, but always in combination with some other grain, such as corn or barley, or, better, with some protein-rich concentrate, such as soybeans, linseed meal, heavy wheat middlings, alfalfa hay, etc. It is not so useful for fattening hogs in cold weather as wheat or barley, and produces a softer pork than those grains. **(243)**

953. Buckwheat.—In a 77-day trial by Robertson at the Ottawa Station,[29] in which 100-lb. pigs were fed either ground buckwheat or ground wheat soaked 30 hours before feeding, the pigs fed buckwheat gained 1.2 lbs. per head daily, compared with 0.8 lb. for those fed wheat. However, for 100 lbs. gain the pigs required over 8 per ct. more buckwheat than corn. In another trial R. Robertson of the Nappan, Nova Scotia, Experimental Farm[30] found that buckwheat, fed with skim milk to 85-lb. pigs, was a little lower in feeding value than the same weight of wheat middlings. Grisdale of the Ottawa Station[31] states that buckwheat produces a poor quality of bacon. **(244)**

954. Pigeon-grass seed.—Western grain elevators screen great quantities of pigeon-grass seed from wheat. At the Wisconsin Station[32] the senior author tested its value as a food for swine. Since the pigs refused to eat any large quantity of the raw pigeon-grass seed meal, it was cooked, after which treatment it was readily consumed. A ration containing 2 parts cooked pigeon-grass seed meal and 1 part corn meal was found to be fully equal to one of corn meal for fattening pigs. A lot fed 1 part raw pigeon-grass seed meal and 2 parts corn meal gave poorer

[28] S. D. Bul. 83.
[29] Ottawa Expt. Farms, Rpt. 1894.
[30] Ottawa Expt. Farms, Rpt. 1901.
[31] Ottawa Expt. Farms, Bul. 51.
[32] Wis. Rpt. 1894.

returns, tho still justifying the use of this weed seed when it can be had at low cost or would otherwise be wasted. To be satisfactory for pigs, pigeon-grass seed should be both ground and cooked.

955. Lamb's quarter or pig weed.—Lamb's quarter, *Chenopodium album,* is a common weed in the wheat fields of Manitoba and the North West. In a trial at the Manitoba Experimental Farms[33] 100 lbs. of lamb's quarter seed screened from wheat was found to be equal to 60 lbs. of mixed grain when constituting one-fifth of the ration for pigs.

956. Garbage.—Garbage, or household waste, may be fed to swine, but care must be taken that dishwater containing lye or washing soda, broken dishes, etc., which are apt to cause death, be kept apart from the materials having food value.[34] As there is likewise danger of poisons resulting from the decay of the garbage, the material should be thoroly cooked in all doubtful cases.

Minkler[35] reports that in New Jersey, especially in the vicinity of Secaucus, thousands of pigs are fattened on garbage collected from New York and other cities. In some instances the garbage is fed without sorting or any treatment except partial drying. At other plants the grease is extracted and skimmed off in rendering vats, and the residue carefully sorted. In some cases it is run thru steam digesters, concentrated, and put on the market as garbage tankage, which is used chiefly as a fertilizer. In other cases, the residue remaining after the grease is removed is thinned with water, elevated to storage tanks, and from thence carried by troughs to feeding pens. Here pigs are fed garbage, swill, and stale bread as the sole ration. Large gains are not secured, but all the income from the pigs is often profit, the grease paying for the expense of collecting and treating the garbage and for all labor.

In a trial with 200-lb. pigs, Minkler secured satisfactory gains with such mixtures as corn meal 4 parts, molasses 2 parts, and garbage tankage 9 parts; corn meal 4 parts, skim milk 18 parts, and garbage tankage 9 parts; and corn meal 4 parts, molasses 2 parts, skim milk 18 parts, and garbage tankage 9 parts. The garbage tankage was of about the same consistency as molasses. At first the pigs refused any feed containing the garbage tankage, but were gradually accustomed to it. The flesh of the pigs fed garbage tankage was firm and of good color.

II. Nitrogenous Concentrates

957. Dairy by-products.—Skim milk and buttermilk are ideal feeds for swine, especially growing pigs and brood sows. Rich in digestible protein and carrying much mineral matter, they should never be fed alone but always in combination with such starchy feeds as corn, barley, wheat, kafir, milo, emmer, and millet. This combination stands unexcelled for producing economical growth and for fattening. Indeed, where skim milk or buttermilk is used as a supplement to corn or other cereals,

[33]Ottawa Expt. Farms, Rpt. 1902. [34]N. Y. (Cornell) Bul. 141. [35]N. J. Cir. 40.

the gains will usually be slightly larger than with any other supplement. (**118**) For example, Skinner and Cochel[36] obtained the following results in a 60-day trial with 114-lb. pigs in which skim milk, tankage, wheat middlings, linseed meal, and soybean meal were fed as supplements to corn meal, about the same amount of protein being fed each lot:

Skim milk compared with other nitrogenous supplements for pigs

Average ration			Daily gain	Feed for 100 lbs. gain Corn	Supplement
			Lbs.	Lbs.	Lbs.
Lot I,	Skim milk, 9.0 lbs.	Corn, 6.0 lbs......	2.02	297	445
Lot II,	Tankage, 0.44 lb.	Corn, 6.6 lbs......	1.83	359	24
Lot III,	Middlings, 3.6 lbs.	Corn, 3.6 lbs......	1.97	181	180
Lot IV,	Linseed meal, 0.73 lb.	Corn, 5.8 lbs......	1.75	333	42
Lot V,	Soybean meal, 0.84 lb.	Corn, 5.8 lbs......	1.82	321	46

Large and economical gains were made by all lots, but skim milk slightly excelled the other supplements. Dairy by-products are so useful for pigs that the breeder of pure-bred swine should in many cases keep a dairy in order to have the by-products for the sows and their young. (**266-8**)

It has been emphasized before that skim milk, buttermilk, or whey should always be pasteurized at the creamery or cheese factory before being returned to the farm, in order to prevent the spread of tuberculosis and other diseases. Swine are especially susceptible to tuberculosis and may contract the disease not only from infected milk, but, as Kennedy and Dinsmore found at the Iowa Station,[37] by following tuberculous cattle to work over the droppings. (**269**)

958. Skim milk.—That skim milk should not be fed alone is shown in an 86-day trial by Beach and Garrigus at the Connecticut (Storrs) Station.[38] Pigs averaging 25 lbs. in weight, fed skim milk alone, gained only 0.72 lb. per head daily and required 2,739 lbs. of milk for 100 lbs. of gain. Others which were fed 3.2 lbs. of grain and 12.9 lbs. of skim milk per head daily gained 1.38 lbs. and required only 233 lbs. grain and 935 lbs. skim milk for 100 lbs. gain.

The value of skim milk when fed with corn or the other cereals has been determined at several stations. The following table summarizes the results secured in some of these trials:

Grain value of skim milk for pigs

	Milk required to equal 100 lbs. of grain
	Lbs.
Fjord, Copenhagen (Denmark) Station, Rpt. 1887................	600
Grisdale, Ottawa (Canada) Expt. Farms, Bul. 33.................	604
Linfield, Utah Bul. 94..	495
Soule and Fain, Tenn., Bul. Vol. XVI, No. 3......................	476
The senior author, Wis. Rpt. 1895..............................	475

[36] Ind. Bul. 137. [37] Iowa Bul. 107. [38] Conn. (Storrs) Bul. 39.

It is shown that when properly combined with concentrates, from 475 to 600 lbs. of separator skim milk has a feeding value equal to 100 lbs. of corn or other grain.

Clinton of the New York (Cornell) Station[39] recommends that, in starting pigs on a ration containing a large quantity of skim milk, care be exercised lest at first the pigs be overfed.

Cooke of the Vermont Station[40] found that pigs fed sour skim milk were more thrifty than those getting sweet skim milk. According to Day[41] sweet milk is better for very young pigs. (266)

959. Proper proportion of skim milk to grain.—To determine the proper proportion of skim milk to feed with meal to pigs, the senior author conducted 19 feeding trials at the Wisconsin Station[42] in which a total of 88 pigs, usually weighing 100 lbs. or over, were fed varying amounts of skim milk with corn meal. In the following table the results are arranged in groups according to the amount of skim milk fed per pound of corn meal. The last column shows the amount of skim milk required to save 100 lbs. of corn meal, assuming that 500 lbs. of corn meal fed alone would have produced 100 lbs. of gain.

Skim milk and corn meal required for 100 lbs. of gain by pigs

Proportion of milk to corn meal	Feed for 100 lbs. gain Corn	Feed for 100 lbs. gain Milk	Milk to replace 100 lbs. corn
	Lbs.	Lbs.	Lbs.
1 lb. corn meal with 1 to 3 lbs. milk	321	585	327
1 lb. corn meal with 3 to 5 lbs. milk	265	1,048	446
1 lb. corn meal with 5 to 7 lbs. milk	250	1,434	574
1 lb. corn meal with 7 to 9 lbs. milk	207	1,616	552

The table brings out plainly the important fact that skim milk has the highest value when not over 3 lbs. of milk are fed with each pound. of corn meal to pigs weighing 100 lbs. or over. The nutritive ratio of a ration of 1 part corn and 3 parts skim milk is 1:5.2, which is slightly too wide for pigs just after weaning. For pigs of this age 4 or 6 parts of skim milk to 1 part of corn should be ample. Larger allowances of skim milk may be fed than here stated with entirely satisfactory gains when a surplus is at hand, but the milk will not then have as high a value as when only sufficient is given to balance the ration properly.

960. Money value of skim milk.—The feeder desirous of knowing the money value of skim milk compared with corn at varying prices will gain help from the following table, derived from the previous study:

Money value of 100 lbs. of skim milk

	When 1 lb. of corn meal is fed With 1 to 3 lbs. of milk	When 1 lb. of corn meal is fed With 7 to 9 lbs. of milk	Average of all trials
	Cents	Cents	Cents
Corn at $16 per ton or 44.8 cents per bushel	24	15	17
Corn at $18 per ton or 50.4 cents per bushel	28	16	19
Corn at $20 per ton or 56.0 cents per bushel	31	18	21
Corn at $30 per ton or 84.0 cents per bushel	46	27	32

[39]N. Y. (Cornell) Bul. 199.
[40]Vt. Rpt. 1891.
[41]Productive Swine Husbandry, p. 210.
[42]Wis. Rpt. 1895.

The table shows that when corn is worth $16 per ton, or 44.8 cents per bu. of 56 lbs., separator skim milk has a value of 24 cents per 100 lbs., provided not over 3 lbs. of skim milk is fed with each pound of corn. Should the feeder give as much as 7 to 9 lbs. of skim milk with each pound of corn, then the milk is worth but 15 cents per 100 lbs.

The above measures in a general way the value of skim milk when combined with corn for fattening pigs. Those familiar with this feeding stuff and its worth for bone and muscle building know that in many cases, especially for young pigs and brood sows, its value is much higher than stated.

A rule by Hoard for finding the money value of skim milk when fed to fattening pigs is in substance:

> To find the value of 100 lbs. of skim milk when fed alone, multiply the market price of live hogs in cents per pound by 5; if fed in combination with corn or barley, multiply by 6.

According to this rule, when live hogs are worth 5 cents per pound, each 100 lbs. of milk is worth 25 cents when fed alone, and 30 cents when fed with corn or barley meal.

The Gurler rule proposed many years ago is:

> The value of 100 lbs. of skim milk when fed along with corn to fattening hogs is half the market price of corn per bushel.

By this rule, when corn is worth 50 cents per bushel, skim milk is worth 25 cents per 100 lbs. for fattening hogs, if combined with corn or some other suitable grain.

961. Whole milk.—On account of the high value of butter fat for human food it is not profitable to feed whole milk to pigs. Scheven[43] found that when whole cow's milk was fed to 12-weeks-old pigs, from 900 to 1,620 lbs. was required to produce 100 lbs. of gain, the average being 1,253 lbs. Linfield concludes from a trial at the Utah Station[44] that whole milk is worth only about twice as much as skim milk for pigs. This shows that ordinarily one cannot afford to feed whole cow's milk to pigs. (**265**) Beach of the Connecticut (Storrs) Station[45] has shown that cow's milk rich in fat is far from satisfactory as a feed for young pigs. (**117**)

962. Buttermilk.—The value of buttermilk and skim milk has been compared by Goessmann in a 125-day trial at the Massachusetts Station[46] and by Wilson in two 62-day trials at the South Dakota Station[47] with the results shown in the table:

Buttermilk vs. skim milk for pigs

Average ration		Initial weight	Daily gain	Feed for 100 lbs. gain Corn	Feed for 100 lbs. gain Milk
		Lbs.	Lbs.	Lbs.	Lbs.
Lot I, Buttermilk, 17.1 lbs.	Corn, 4.1 lbs...	77	1.67	249	1,026
Lot II, Skim milk, 17.2 lbs.	Corn, 4.0 lbs...	77	1.67	246	1,036

[43] Martiny, Die Milch.
[44] Utah Bul. 94.
[45] Conn. (Storrs) Bul. 31.
[46] Mass. Rpt. 1884.
[47] S. D. Bul. 136.

The pigs in Lot I, fed buttermilk and corn, made just as large and economical gains as those in Lot II, fed skim milk and corn. These trials support the general experience that where no water has been added buttermilk is fully equal to skim milk for pig feeding. (267)

963. Whey.—In pig-feeding trials by Day at the Ontario Agricultural College[48] and by the senior author at the Wisconsin Station[49] whey fed in combination with meal of the mixed grains gave the following returns:

481 lbs. of mixed grain when fed alone produced 100 lbs. of gain.
303 lbs. of mixed grain with 1,398 lbs. of whey produced 100 lbs. gain.

Since 1,398 lbs. of whey saved 178 lbs. of grain, 785 lbs. of whey was equal to 100 lbs. of grain. The whey used in the Wisconsin trials was richer in fat than the average. Fjord of the Copenhagen (Denmark) Station[50] estimates that for swine feeding in Denmark, where the whey is poorer than with us, 1,200 lbs. is equal to 100 lbs. of mixed grain. From the above we may conclude that, when properly combined with corn and barley meal, 1,000 lbs. of ordinary whey is worth 100 lbs. of corn meal for fattening swine. Accordingly, whey is worth about half as much as skim milk for pig feeding. As whey contains only a fair amount of protein, it should be fed along with some protein-rich concentrate, like tankage, wheat middlings, or linseed meal.

Day,[51] states that the first slight fermentation which whey undergoes does not seriously detract from its value for pig feeding. Day[52] further found that ordinary whey was worth from 25 to 30 per ct. more than separated whey. (268)

964. Tankage; meat meal.—The value of tankage or meat meal as a supplement to corn or other carbonaceous concentrates has been demonstrated in trials at many stations and by experience on many farms. Rich in protein which is well-balanced in composition (118) and likewise high in calcium and phosphorus, tankage is excelled only by skim milk or buttermilk in producing thrifty growth and large gains. Since tankage or meat meal for stock feeding is thoroly cooked under pressure at a high temperature, there is no danger of spreading disease by its use. (270) To illustrate the value of tankage as shown in the trials at the various stations there are given in the following table the results of 2 trials of 127 and 100 days, respectively, in which various proportions of tankage were fed as supplements to corn, and 1 trial of 56 days in which different amounts of tankage were used as supplements to corn for pigs running on alfalfa pasture:

[48] Ontario Agr. Col., Rpt. 1896.
[49] Wis. Rpt. 1891.
[50] Copenhagen (Denmark) Station, Rpt. 1887.
[51] Ontario Agr. Col., Rpt. 1897.
[52] Ontario Agr. Col., Rpt. 1909.

Tankage or meat meal as supplement to corn

Average ration	Supplement fed	Initial weight	Daily gain	Feed for 100 lbs. gain
	Per ct.	Lbs.	Lbs.	Lbs.
Indiana Station, 12 pigs, fed 127 days *				
Lot I, Corn meal, 3.5 lbs....................	0	64	0.7	520
Lot II, Tankage, 0.4 lb. Corn meal, 3.9 lbs....	9	66	1.2	370
Lot III, Tankage, 0.7 lb. Corn meal, 3.9 lbs....	17	65	1.2	378
Iowa Station, 48 pigs, fed 100 days †				
Lot I, Corn meal, 6.5 lbs....................	0	135	1.2	557
Lot II, Meat meal, 0.8 lb. Corn meal, 7.6 lbs...	9	137	1.9	451
Lot III, Meat meal, 0.9 lb. Corn meal, 7.3 lbs...	11	140	1.7	457
Lot IV, Meat meal, 1.0 lb. Corn meal, 6.7 lbs...	13	136	1.8	436
Nebraska Station, 30 pigs, fed 56 days ‡				
Lot I, Soaked corn, 5.2 lbs..................	0	145	1.3	416
Lot II, Tankage, 0.3 lb. Soaked corn, 5.3 lbs...	5	144	1.5	371
Lot III, Tankage, 0.6 lb. Soaked corn, 5.0 lbs...	10	144	1.5	366

*Plumb and VanNorman (Ind. Bul. 90). †Kennedy and Robbins (Iowa Bul. 91).
‡Burnett (Nebr. Bul. 94).

In the Indiana trial the ration containing 9 per ct. tankage produced slightly more economical gains than the one containing 17 per ct. In this trial 100 lbs. of tankage, when forming 9 per ct. of the ration, replaced 555 lbs. of corn. In the Iowa trial, with older pigs, the ration containing 9 per ct. meat meal produced the largest gains, 100 lbs. of the meat meal replacing 359 lbs. of corn. In the Nebraska trial, with pigs on alfalfa pasture, 5 per ct. of tankage produced as large gains as 10 per ct., due to the fact that the protein-rich alfalfa largely balanced the corn allowance. From these and other trials we may conclude that when high grade tankage, carrying 55 per ct. of protein or over, is fed as the sole supplement to corn to pigs over 100 lbs. in weight, not over 9 to 10 per ct. is needed to balance the ration. With mature pigs the proportion of tankage may be reduced even lower. With young pigs soon after weaning it is advisable to feed as high as 20 per ct. of tankage, or better, feed 9 to 10 per ct. of tankage and add sufficient linseed meal, wheat middlings, etc., to provide the proper amount of protein for animals of this age. (**Appendix Table V**) Where a lower grade of tankage is fed the amount supplied should be correspondingly increased. For pigs fed corn on such protein-rich pasture as alfalfa, clover, soybean, cowpea, or rape, 5 per ct. of high grade tankage is usually sufficient to balance the ration. (**985**)

965. Tankage as sole supplement vs. tankage and shorts.—To determine the effectiveness of tankage as the sole supplement to corn, compared with both tankage and wheat shorts, Waters, Kinzer, Wheeler, Wright, and King[53] conducted 4 trials, averaging 62 days, at the Kansas Station with a total of sixty-three 145-lb. pigs, obtaining the results shown in the table:

[53]Kan. Bul. 192.

Tankage alone vs. tankage and shorts as supplements to corn

Average ration		Daily gain Lbs.	Feed for 100 lbs. gain Lbs.	Feed cost of 100 lbs. gain* Dollars
Lot I, Tankage, 0.70 lb.	Corn, 6.3 lbs......	1.44	485	5.20
Lot II, Tankage, 0.52 lb. Shorts, 2.03 lbs.	Corn, 4.9 lbs......	1.60	460	5.11

*Corn at $19, shorts at $24, and tankage at $41 to $45 per ton.

In each of the 3 trials Lot II, fed both tankage and shorts to supplement the corn, made slightly the most rapid gains, and, with feeds at the prices stated, the cheapest gains in all but 1 of the trials. It seems probable that these results are due to the greater variety of proteins furnished when both tankage and shorts are fed as supplements to corn.

966. Tankage vs. linseed meal.—At the Indiana Station[54] Skinner and Cochel, in 3 trials averaging 57 days, compared tankage and linseed meal as supplements to corn meal with a total of 43 pigs, averaging 164 lbs. in weight. Since tankage contains almost twice as much digestible crude protein as linseed meal, only half as much of the former was fed.

Tankage compared with linseed meal as supplements to corn

Average ration		Daily gain Lbs.	Total gain Lbs.	Feed for 100 lbs. gain Lbs.
Lot I, Corn, 6.0 lbs.	Tankage, 0.3 lb.........	1.6	94	381
Lot II, Corn, 5.5 lbs.	Linseed meal, 0.6 lb.....	1.5	89	394

The table shows that when fed with corn 0.3 lb. tankage produced slightly larger and more economical gains for feed consumed than twice as much linseed meal.

967. Tankage for pigs following corn-fed steers.—At the Ohio Station[55] Carmichael placed one 108-lb. pig with each 2 steers fattening on a ration composed mostly of corn. The corn voided by the steers was ample for the pigs, not all being consumed. Half of the pigs were each given one-third of a pound of tankage daily. The pigs on droppings alone gained 1 lb. each daily, and those getting tankage in addition, 1.5 lbs. For each 100 lbs. of tankage fed, the pigs made 162 lbs. of extra gain.

968. Blood meal vs. skim milk.—In experiments at the Virginia Station[56] Quick and Spencer found blood meal and skim milk about equal in value as supplements to corn, when fed on the basis of equal pounds of protein. Blood meal at $3 per 100 lbs. was as valuable as skim milk at 25 cents per 100 lbs. It was found necessary to mix blood meal with about its own weight of wheat middlings for the pigs to relish it. Day[57] states that since blood meal is a highly concentrated feed it must be fed in small amount and with care to avoid injurious results. **(271)**

969. Wheat middlings, or shorts.—Wheat middlings, or shorts, are one of the most popular nitrogenous supplements for pigs. They are rich in protein and phosphorus, but are relatively low in calcium. Hence

[54]Ind. Bul. 126. [55]Ohio Cir. 73. [56]Va. Bul. 176. [57]Ontario Agr. Col., Rpt. 1905.

when middlings are used as the sole supplement to corn for pigs in dry lots, it is important to supply additional calcium in the form of ground limestone, slaked lime, etc. (**927**) That it is not economical to feed middlings alone to swine is shown in a trial by the senior author[58] with 3 lots, each of 3 pigs, fed the following rations for 6 weeks:

Wheat middlings alone vs. middlings and corn

Average ration	Daily gain	Total gain	Feed for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Lot I, Corn meal, 4.4 lbs	0.8	35	537
Lot II, Wheat middlings, 4.0 lbs	0.8	32	522
Lot III, Corn meal and middlings, 3.8 lbs	0.9	36	439

While the pigs fed either corn meal or wheat middlings alone required over 500 lbs. of feed for 100 lbs. of gain, those in Lot III, fed equal parts of middlings and corn, consumed only 439 lbs. of feed per 100 lbs. of gain. As has been pointed out (**965**), when both middlings and tankage are fed as supplements to corn, larger gains are generally secured than with either middlings or tankage as the sole supplement. In a trial by Carroll at the Utah Station[59] with 2 lots, each of 6 pigs fed 84 days, adding 1 part of tankage to the already fairly well-balanced mixture of 6 parts wheat shorts and 5 parts barley did not increase the gains sufficiently to prove profitable. Middlings are often useful for mixing with other feeds as they make a fine textured, palatable slop. (**220**)

970. Wheat shorts vs. tankage.—To compare the value of wheat shorts and high-grade tankage as supplements to corn, Erf and Wheeler fed 2 lots, each of ten 128-lb. pigs, the following rations for 45 days at the Kansas Station:[60]

Wheat shorts vs. tankage as supplements to corn

Average ration		Daily gain	Feed for 100 lbs. gain: Corn	Feed for 100 lbs. gain: Supplement	Feed cost of 100 lbs. gain
		Lbs.	Lbs.	Lbs.	Dollars
Lot I, Shorts, 2.40 lbs.	Corn meal, 4.79 lbs.	1.5	319	160	4.95
Lot II, Tankage, 1.16 lbs.	Corn meal, 5.82 lbs.	1.6	364	73	4.92

While the pigs fed tankage made slightly the larger gains, the feed cost of 100 lbs. gain was about the same for both the lots, with corn at $19, shorts at $24, and tankage at $40 per ton.

971. Red dog flour.—At the Virginia Station[61] 54-lb. pigs were fed soaked red dog flour and corn meal, equal parts, for 58 days. They gained 1.3 lbs. daily, requiring but 390 lbs. of the mixture for 100 lbs. of gain, while on the same feed given dry 490 lbs. were required. The high value of red dog flour when properly fed is here shown. This feed serves its highest purpose with quite young pigs, which need a highly digestible, palatable feed, containing little fiber. (**219**)

[58] Wis. Rpt. 1885.
[59] Information to the authors.
[60] Kan. Bul. 192.
[61] Va. Bul. 167.

972. Wheat bran; wheat mixed feed.—Bran is too bulky a feed to be fed in any large amount to fattening pigs, for which middlings or shorts are far preferable. Where clover or alfalfa hay, roots, or other cheaper bulky feeds are not available, a limited amount of wheat bran is helpful in adding nutriment and volume to the otherwise meager ration usually given brood sows and shotes not being fed for gain. At the Maine Station[62] Jordan found wheat middlings twice as valuable as wheat bran for fattening pigs, and at the Copenhagen (Denmark) Station[63] bran gave unsatisfactory results when fed alone to pigs. (**218**)

At the Kentucky Station[64] Good obtained satisfactory results with a good grade of wheat mixed feed (shipstuff) which contained all the middlings, when fed with an equal weight of corn meal to fattening pigs. (**221**)

973. Linseed meal.—The value of this feed compared with tankage as a supplement to carbonaceous feeds has already been discussed. (**966**) The value of linseed meal compared with other protein-rich concentrates is further shown in a trial by Forbes at the Missouri Station[65] in which 6 lots, each of 5 pigs averaging 93 lbs., were fed for 90 days on corn meal supplemented with the feeds shown in the table:

Linseed meal compared with other nitrogenous concentrates

Supplement fed with each 100 lbs. of corn	Average ration Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Lbs.
Lot I, Linseed meal, 20 lbs.	6.4	1.4	445
Lot II, Wheat middlings, 100 lbs.	5.2	1.0	502
Lot III, Wheat middlings, 50 lbs.	5.0	1.0	518
Lot IV, Linseed meal, 10 lbs. Germ oil meal, 10 lbs.	5.5	1.2	476
Lot V, Linseed meal, 10 lbs. Gluten meal, 10 lbs.	5.6	1.2	483
Lot VI, Linseed meal, 10 lbs. Gluten feed, 10 lbs.	5.9	1.3	452

Lot I, fed linseed meal as the sole supplement to corn meal, made the largest and most economical gains. The lots fed middlings and corn required from 13 to 16 per ct. more concentrates for 100 lbs. gain than those fed linseed meal and corn. When germ oil meal, gluten meal, or gluten feed was substituted for half the linseed meal, the rate of gain was lowered and the amount of grain required for 100 lbs. gain increased. Gluten feed proved slightly more valuable than gluten meal or germ oil meal. Forbes writes that the pork from pigs fed linseed meal was characterized by hard, white fat. As large an allowance of linseed meal as is necessary to balance a ration of corn or other cereals is often rather unpalatable to pigs. Hence many feeders prefer to feed less linseed meal and a small allowance of other supplements, such as skim milk, tankage, or middlings. A small allowance of linseed meal is often highly beneficial, especially with brood sows before farrowing, on account of its slightly laxative effect. Because of its mucilaginous nature linseed meal makes a slop of uniform, creamy consistency. (**254**)

[62] Me. Rpt. 1889.
[63] Copenhagen (Denmark) Station, Rpt. 1892.
[64] Ky. Bul. 175.
[65] Mo. Bul. 67.

974. Cottonseed meal.—As now prepared, cottonseed meal is poisonous to swine. All the various proposed ways for safely feeding this meal have failed under careful and continued tests. Pigs thrive at first on the meal, but usually in from 4 to 6 weeks some die—not all, as a rule,—but so many that all possible profits from the use of this feed are lost. A few feeders continue to use the meal, experience enabling them to avoid most of the losses. If cottonseed meal is not fed continuously for over 40 days and does not form over one-fourth of the ration, and if the pigs are freely supplied with green forage or grazed on pasture, the risk from this feed is slight. It is considered safe to have pigs follow steers which are being fed cottonseed meal, for the meal does not seem to be poisonous after passing thru the cattle. Care should always be taken that the steers do not throw so much meal out of the feed boxes that the pigs may be poisoned by eating such waste meal. (**249**)

975. Field peas.—These leguminous seeds, rich in protein, are well suited to supplement corn and the other carbonaceous grains. While trials[66] have shown that peas alone produce fair gains, larger and much cheaper gains are secured when only sufficient of this rich feed is used to balance the ration properly. According to Grisdale,[67] pigs fed solely on pea meal in dry lots do not thrive.

Cottrell[68] reports that in the San Luis valley, Colorado, field peas are grown on irrigated land and the vines allowed to mature and cure on the ground. Pigs are then turned into the fields to fatten on the peas alone, an acre of good peas producing about 400 lbs. of gain. Sometimes the unthreshed vines, after being stacked, are fed to pigs in yards, an acre of good peas producing from 600 to 800 lbs. of gain. Pork from pigs so fattened is firm, sweet, and tender, with a delicious flavor. Cottrell recommends feeding barley, wheat, potatoes, or roots once a day to pigs foraging on peas. (**261**)

976. Cull beans.—Cull table beans are satisfactory for swine when thoroly cooked and fed with carbonaceous feeds. At the Michigan Station[69] in 3 trials of from 56 to 70 days with 26 pigs, averaging 160 lbs., Shaw and Anderson found that pigs fed equal parts of cooked cull beans and corn meal made average gains of 1.5 lbs. per head daily, requiring 406 lbs. of feed for 100 lbs. of gain. Pigs fed beans alone made daily gains of only 1.1 lbs. and required 421 lbs. of beans for 100 lbs. gain. Salt should always be added to the water in which the beans are cooked. When beans are fed alone or in excess they produce a soft pork lacking in quality. (**263**)

977. Soybeans.—Soybeans, rich in protein, are a valuable supplement for corn or other grains. In the following table are summarized the results of 5 trials, averaging 70 days, in which soybeans have been compared with tankage as a supplement to corn.

[66] Wis. Rpt. 1902; S. D. Bul. 38.
[67] Ottawa Expt. Farms, Bul. 51.
[68] Colo. Bul. 146.
[69] Mich. Bul. 243.

Soybeans vs. tankage as supplements to corn

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Lbs.
Lot I, total of 37 pigs *			
Soybeans, 0.90 lb. Corn, 4.7 lbs.	110	1.37	409
Lot II, total of 33 pigs *			
Tankage, 0.63 lb. Corn, 5.1 lbs.	109	1.46	382

*Average of 1 trial by Erf and Wheeler (Kan. Bul. 192), 2 by Good (Ky. Bul. 175), 1 by Skinner (Ind. Bul. 108), and 1 by Skinner and Cochel (Ind. Bul. 137).

Lot I, fed soybeans and corn, made entirely satisfactory gains, only slightly smaller than Lot II, fed tankage and corn. In these trials 0.90 lb. of soybeans per head daily was nearly as effective in supplementing the corn allowance as was 0.63 lb. of tankage.

In each of 2 trials by Skinner and Cochel[70] at the Indiana Station pigs fed soybeans and corn made slightly larger gains and required slightly less feed for 100 lbs. gain than others fed linseed meal and corn. When fed in too large amount soybeans produce soft pork, dark and dull in color. At the Wisconsin Station[71] Humphrey found that when 1 part of soybeans and 2 parts of corn were fed to pigs receiving skim milk, soybeans were worth 10 per ct. more than wheat middlings, so far as gains were concerned. However, when this proportion of soybeans was fed the pork was less firm and the grain of the meat and the distribution of fat and lean less satisfactory than with pigs fed middlings, corn, and milk. Soybeans are commonly ground for pigs. **(256)**

978. Cowpeas.—In the South cowpeas are of great importance in economical pork production. The seed may be used as a supplement to corn or other carbonaceous feeds, or the pigs may be turned into the field to harvest the crop when the pods are well matured. **(990)** The following table presents the results of 3 trials in which the value of cowpeas and corn for pigs has been compared:

Cowpeas for fattening pigs

Average ration	Initial weight	Daily gain	Feed for 100 lbs. gain
Duggar, Ala. Bul. 82	Lbs.	Lbs.	Lbs.
Lot I, Corn, 2.5 lbs.	58	0.5	487
Lot II, Cowpeas, 2.8 lbs.	60	0.6	481
Lot III, Corn, 1.4 lbs. Cowpeas, 1.4 lbs.	62	0.6	433
Duggar, Ala. Bul. 143			
Lot I, Corn, 3.5 lbs.	63	0.7	478
Lot II, Corn, 1.7 lbs. Cowpeas, 1.9 lbs.	67	0.9	395
Newman and Pickett, S. C. Bul. 52			
Lot I, Corn, 9.2 lbs.	156	1.4	602
Lot II, Ground cowpeas, 6.7 lbs.	160	1.1	491

In the Alabama trials cowpeas and corn were practically equal in feeding value when fed separately, but a mixture of both proved more satisfactory than either alone, as would be expected from the composition of

[70] Ind. Buls. 126, 137. [71] Wis. Rpt. 1905.

these feeds. The South Carolina test was decidedly in favor of the cowpeas. (**262**)

979. Peanut.—This leguminous plant is of great and increasing importance in the South for the feeding of swine. Pigs are commonly turned into the fields to do their own harvesting, as is pointed out later(**1005**), or the peanut cake or meal resulting from the manufacture of peanut oil may be used as supplements to carbonaceous feeds. If pigs are fattened on peanuts alone soft pork is produced, but this may be overcome by feeding them corn for the last part of the finishing period. (**258**)

980. Rice by-products.—To compare the value of rice meal and corn meal, Lindsey divided a litter of six 10-weeks-old pigs into 2 lots and fed them for 92 days at the Massachusetts Station.[72] The pigs in one lot were fed 3.1 lbs. of rice meal and 13.0 lbs. of skim milk and those in the other an equal weight of corn meal with the same amount of skim milk. The 2 lots made the same gains, showing that rice meal was equal to corn meal. At the South Carolina Station[73] Conner found rice meal slightly superior to corn meal when fed with skim milk.

Dvorachek fed 8 lots, each of five 140-lb. pigs, the rations shown in the table for 63 days at the Arkansas Station,[74] to determine the value of rice bran and rice polish compared with corn chop:

Rice bran and rice polish vs. corn for pigs

	Average ration		Daily gain	Feed for 100 lbs. gain
			Lbs.	Lbs.
Lot I	Corn, 6.2 lbs.		1.30	476
Lot II	Rice bran, 6.2 lbs.		1.46	423
Lot III	Rice polish, 5.8 lbs.		1.63	358
Lot IV	Corn, 2.1 lbs.	Rice bran, 2.1 lbs. Rice polish, 2.1 lbs.	1.72	363
Lot V	Rice bran, 3.1 lbs.	Rice polish, 3.1 lbs.	1.40	404
Lot VI	Rice bran, 4.1 lbs.	Rice polish, 2.1 lbs.	1.66	369
Lot VII	Rice bran, 1.9 lbs.	Rice polish, 3.9 lbs.	1.49	390
Lot VIII	Rice bran, 1.6 lbs.	Rice polish, 4.6 lbs.	1.72	358

This table shows the high value of rice bran and rice polish for pigs. Lot IV, fed equal parts corn chop, rice bran, and rice polish, and Lot VIII, fed 1 part rice bran and 3 parts rice polish, made the largest gains, and Lots III and VIII required the smallest amount of feed for 100 lbs. of gain. Dvorachek concludes that 100 lbs. of rice polish is equal to 133 lbs. of corn, and that 100 lbs. of rice bran is equal to 112 lbs. of corn. Duggar secured similar results at the Alabama Station,[75] finding 127 lbs. of rice polish equal to 100 lbs. of corn meal. (**234**)

981. Miscellaneous nitrogenous concentrates.—*Dried distillers' grains* are not relished by pigs when fed as the sole concentrate allowance, and, moreover, are too bulky a feed to be supplied in large amounts to fattening pigs. However, they give good results when fed as a supplement

[72] Mass. Rpt. 1897.
[73] S. C. Bul. 55.
[74] Information to the authors.
[75] Ala. Bul. 122.

to corn or the other cereals, as is shown in a trial by Good and Smith at the Kentucky Station.[76] Four lots of 10 to 15 pigs each, averaging 69 lbs., were fed as shown in the table for 73 days, all lots except Lot IV running on rape and oats or rape pasture:

Dried distillers' grains for fattening pigs

Average ration	Daily gain	Concentrates for 100 lbs. gain
	Lbs.	Lbs.
Lot I, Dried distillers' grains, 1.7 lbs. Pasture	0.46	368
Lot II, Corn meal, 3.2 lbs. Pasture	0.93	344
Lot III, Corn meal, 2.6 lbs. Dried distillers' grains, 0.51 lb. Pasture	1.03	300
Lot IV, Corn meal, 3.3 lbs. Dried distillers' grains, 0.66 lb.	0.88	444

When fed as the sole concentrate to pigs on pasture, dried distillers' grains were much inferior to corn. However, a mixture of 1 part distillers' grains and 5 parts corn produced larger and more economical gains than corn alone. Lot I could not be induced to eat more than 1.7 lbs. of distillers' grains per head daily. Lots II and III, however, would have eaten even larger allowances of concentrates than shown in the table but were restricted so as to make more use of the pasture. (**282**)

Distillery slop may be fed to pigs with good results, when concentrates such as corn and the other cereals are supplied in addition, as the slop is too watery to be fed alone.

Gluten meal and gluten feed, as has been shown before (**973**), give satisfactory results when fed with corn and some other supplement, such as linseed meal. It is not advisable, however, to use these corn by-products as the sole supplement to corn for pigs in the dry lot, for the pigs would then receive only corn protein, which, as we have seen (**201**), is somewhat unbalanced in composition. Watson at the New York (Cornell) Station[77] found a mixture of 1 part gluten meal and 4 parts corn meal 7 per ct. more valuable than wheat meal when both were fed with skim milk. (**210-1**)

III. Forage Crops, Pasture, and Other Succulent Feed; Hay

982. Value of forage crops and pasture.—Thru the use of suitable forage and pasture crops, pork may be produced at a much lower cost than where pigs are maintained in dry lots on expensive concentrates alone. Spring pigs will thrive amazingly on good pasture supplemented by a limited allowance of concentrates and if not finished by the close of the pasture season will be in condition to make most economical gains in the dry lot. Not only do pigs at pasture make cheaper gains, but the succulent feed and the exercise they obtain are important aids in keeping them thrifty and in good health. When pigs are fed in dry lots it is difficult to save the manure unless they are confined closely, and thus

[76] Ky. Bul. 190.

[77] N. Y. (Cornell) Bul. 89.

often much fertility is wasted. With pigs at pasture the manure is uniformly distributed on the fields. By the use of forage crops thruout the growing season and legume hay during the winter the cost of maintaining brood sows may be materially reduced. Tho pasturage is of prime value for pigs in all sections of the country, it is especially important in the southern states, where, by a well-selected rotation of pastures, green feed may be furnished thruout nearly the entire year.

As Evvard of the Iowa Station[78] writes: An ideal forage for hogs should show: 1. adaptability to local soil and climate; 2. palatability; 3. a heavy yield of digestible nutrients, being high in protein and mineral matter, especially calcium and phosphorus, and low in crude fiber; 4. succulence; 5. long pasturing season; 6. ability to endure grazing; 7. permanency; 8. reasonable cost and ease of seeding; 9. capability of furnishing quick pasture at any time during the growing season. "These essentials are not found in any single forage, but alfalfa, the clovers, and rape have most of them." (**109**)

983. Amount of grain to feed on pasture.—Owing to the high price of concentrates it is important to determine the minimum amount which should be fed to pigs on pasture for satisfactory results. It is never profitable to force young pigs to subsist on pasture alone. At the Utah,[79] New Mexico,[80] Mississippi,[81] and Oklahoma[82] Stations alfalfa pasture proved little more than a maintenance ration for growing pigs. At the Kentucky Station[83] Good found that 63-lb. pigs did not maintain their weight on good rye pasture, and 82-lb. pigs barely held their own on mixed clover and bluegrass pasture. Good states that full-grown brood sows, in thin condition and not suckling pigs, will take on flesh when grazing good pasture without grain. Snyder reports that during a trial of 70 days at the North Platte, Nebraska, Substation[84] mature hogs, thin in flesh, gained about 0.5 lb. daily on alfalfa pasture without grain.

At the Utah Station[85] a series of trials extending over 12 years was conducted, chiefly by Linfield, to determine the most profitable amount of grain to feed to pigs on pasture, which was principally alfalfa. The results of the trials, which were with pigs weighing 60 to 75 lbs. at the start, are summarized in the following table:

Amount of grain to feed pigs on pasture

	No. of pigs	Daily gain	Grain for 100 lbs. gain
		Lbs.	Lbs.
Full grain ration, in pens	74	0.9	484
Full grain ration, on pasture	20	1.2	413
Three-fourths grain ration, on pasture	17	1.0	383
One-half grain ration, on pasture	16	0.7	304
One-fourth grain ration, on pasture	10	0.5	247
Pasture only	19	0.2	...
Green alfalfa only, in pens	2	−0.3	...

[78]Iowa Bul. 136. [79]Utah Bul. 94. [80]N. M. Bul. 90. [81]Miss. Rpt. 1905. [82]Okla. Rpt. 1899. [83]Ky. Bul. 175. [84]Nebr. Bul. 99. [85]Utah Bul. 94.

We learn that the pigs on a full grain ration in pens gained 0.9 lb. each daily and required 484 lbs. of grain for 100 lbs. of gain, while those getting a full grain ration on pasture gained 1.2 lbs. each daily, pasturage effecting a saving of about 15 per ct. in the grain required to produce 100 lbs. gain. The pastured pigs getting a limited grain ration ate less grain for each 100 lbs. of gain than when fed a full grain ration, but also made smaller daily gains, the fattening period being thereby lengthened. If the full grain ration on pasture would have fattened pigs in 100 days, the quarter grain ration would have required 245 days.

Linfield states[86] that pigs fed a limited grain ration on pasture, when later put on full feed, made rapid gains at slightly less cost than those fed a full ration from the start. Hence, for growing pigs to be fattened later, a restricted grain ration on pasture is economical.

984. Alfalfa pasture.—Wherever it thrives alfalfa is the best permanent pasture crop for pigs, since there is no danger from bloat, as with cattle and sheep. (340) Alfalfa provides pasturage during a longer season than almost any other single crop, starting early in the spring and remaining green and succulent in late summer when bluegrass has dried up and even clover is often somewhat hard and woody. Since heavy pasturing of alfalfa is injurious to the stand, the number of pigs should be restricted and the plants allowed to grow up, being cut for hay 2 or 3 times a year. In tests at the Iowa Station by Evvard and Kennedy[87] in which pigs were fed corn and tankage on alfalfa pasture the alfalfa produced 623 to 865 lbs. of pork per acre, after deducting the gains to be credited to the concentrates fed, and without crediting the alfalfa with the hay cut from the pasture. In one trial an acre of alfalfa carried an average of over 16 spring pigs for 180 days, producing 1.05 lbs. of gain per head daily. With corn at $0.50 per bushel and tankage at $50 per ton, the concentrates fed cost only $3.40 per 100 lbs. of gain.

The most profitable amount of grain to feed pigs on alfalfa pasture will depend on the age of the pigs, the abundance of forage, and the relative cost of concentrates and pasture. At the North Platte, Nebraska, Substation[88] Snyder grazed 3 lots of 47-lb. pigs on alfalfa pasture during each of 2 summers. One lot received a light, the second a medium, and the third a full allowance of shelled corn. The combined results of the trials, lasting 98 and 119 days, respectively, are averaged below:

Light, medium, and heavy corn feeding on alfalfa pasture

Daily allowance of corn	Daily gain	Corn for 100 lbs. gain
	Lbs.	Lbs.
Lot I, Shelled corn, 0.5 lb.	0.4	128
Lot II, Shelled corn, 1.1 lbs.	0.5	221
Lot III, Shelled corn, 2.6 lbs.	0.8	331

[86] Utah Bul. 94. [87] Iowa Bul. 136. [88] Nebr. Bul. 99.

It is shown that Lot I, fed a light grain allowance on alfalfa pasture, required only 39 per ct. as much grain for 100 lbs. gain as Lot III, fed a full corn allowance. Lot III, however, made twice as rapid gains as Lot I. Snyder concludes that a light grain allowance on alfalfa pasture is not economical for growing pigs unless alfalfa is abundant, grain high in price, and market conditions warrant holding the pigs. It is usually more profitable to feed 2 lbs. or more of corn per 100 lbs. of pigs than to feed a lighter ration. From trials at the New Mexico Station[89] Foster and Simpson conclude that in their section, where concentrates are high in price, pigs with abundant alfalfa pasture make the most economical gains when fed only about 1 lb. of grain daily per 100 lbs. live weight.

985. Feeding a supplement with corn on alfalfa pasture.—Pigs fed corn alone on alfalfa pasture make fairly satisfactory gains, since the alfalfa goes far toward balancing the corn allowance. More rapid gains are, however, secured when some nitrogenous concentrate is fed in addition. This is shown in the following table which summarizes the results of 3 trials, averaging 71 days, by Waters, Kinzer, Wright, and King[90] at the Kansas Station in which one lot of pigs was given a full allowance of ground corn on alfalfa pasture while another lot was fed a mixture of 62 per ct. corn, 30 per ct. wheat shorts, and 8 per ct. tankage in addition to the pasture:

Feeding supplement in addition to corn and alfalfa pasture

Average ration	Initial weight	Daily gain	Concentrates for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Lot I, Corn, 3.8 lbs. Pasture	81	0.85	439
Lot II, Corn, shorts, and tankage, 5.4 lbs. Pasture	80	1.49	358

The pigs fed shorts and tankage consumed more feed than those fed only corn in addition to alfalfa pasture, made much larger gains, and required 18 per ct. less concentrates for 100 lbs. gain. Since the ration is partly balanced by the alfalfa, not as much additional supplement is required as with corn in the dry lot. For pigs over 100 lbs. in weight, fed corn on alfalfa pasture, 5 per ct. of high grade tankage or other concentrates furnishing an equivalent amount of digestible protein, will produce about as large and usually more economical gains than a larger proportion. (**964**)

986. Clover pasture.—In the northern and central states red clover is one of the most valuable pasture crops for pigs. Carmichael and Eastwood rank 4 forage crops tested at the Ohio Station[91] as follows, in the order of their efficiency: red clover, rape, soybeans, bluegrass. In Missouri, Mumford and Weaver[92] found it inferior only to alfalfa, and in Iowa, Evvard[93] found it surpassed only by alfalfa and rape. Since

[89] N. M. Bul. 90.
[90] Kan. Bul. 192.
[91] Ohio Bul. 242.
[92] Mo. Bul. 110.
[93] Iowa Bul. 136.

early pasturing may kill clover, pigs should not be turned on until it has made a good growth. Clover does not furnish as constant a supply of succulent feed as does alfalfa, tending to become woody late in the summer, but clipping will aid in inducing a new growth. (**348**) On soils too wet or too acid for red clover, alsike clover may be grown. (**350**) Especially in the southeastern states crimson clover, sown as a winter annual, furnishes valuable spring pasture for pigs. (**353**)

987. Sweet clover.—On soils not well adapted to alfalfa or red clover, sweet clover may often be used to advantage as a pasture for pigs. The first year's growth is best suited to pigs, as it is less coarse and woody. To encourage the growth of new shoots the crop should be pastured reasonably close and the tall growth clipped with a mower. (**352**)

988. Field peas for pasture.—In the northern states field peas, sown either alone or with oats or oats and rape, are a most satisfactory summer forage crop for pigs. The extensive use of field peas in certain valleys of the West has already been mentioned. (**975**) At the Wyoming Station,[94] Faville found that an acre of fair field pea pasture grazed by fattening pigs saved 2,344 lbs. of mixed grain. Ashby and Monroe report that at the Washington Station[95] an acre of oats and peas grazed by pigs netted $39.90 after paying for supplemental feeds and the cost of producing the crop. They state that pigs should be turned in when the earliest pods are ripe and should not be allowed to graze over the whole field, but should be confined to small plots by temporary fences or hurdles. (**355**)

989. Soybean pasture.—In the North the soybean is surpassed by alfalfa, clover, rape, and field peas, except perhaps on light, sandy soil where the soybean may produce a larger crop. In the South, however, the soybean is one of the best allies of the pork producer. The high value of this legume is shown in the following table which summarizes the results of 3 trials by Gray, Ridgeway, and Eudaly, at the Alabama Station.[96] In these trials lots each of four to five 45-lb. pigs, carrying some improved blood, but no better than the average pigs of the district, were fed as indicated for periods of 42 to 81 days:

Value of soybeans for southern pork production

Average ration		Daily gain	Feed for 100 lbs. gain: Corn	Feed for 100 lbs. gain: Pasture	Feed cost of 100 lbs. gain*
		Lbs.	Lbs.	Acres	Dollars
Lot I, Corn meal, 0.75 lb.	Soybean pasture	1.10	68	0.218	2.59
Lot II, Corn meal, 1.39 lbs.	Soybean pasture	1.01	138	0.204	3.36
Lot III, Corn meal, 2.33 lbs.	Soybean pasture	1.33	175	0.123	3.17
Lot IV, Corn meal, 2.28 lbs.		0.38	609	.....	7.61

*Corn, $0.70 per bu. and soybean pasture $8 per acre.

The table shows that where soybean pasture was used pork was made for less than half of what it cost when corn was used alone. During the first few weeks of the grazing period, when the pigs ate no part of the

[94] Wyo. Rpt. 1913. [95] Wash. Pop. Bul. 63. [96] Ala. Bul. 154.

plants except the leaves, as the beans were not yet formed, good gains were made when the pasture was supplemented by corn. During the last few weeks the animals ate nothing but the beans which had fallen from the plants. Excellent gains were made during this time. The amount of corn to feed on soybean pasture will depend on the amount of corn on hand to dispose of, the amount of available pasture, and the length of time in which the animals should be fattened. When prices are low it may be wise to simply carry the hogs along on pasture plus a light grain ration or no grain ration at all until the prices advance. Since a large allowance of soybeans tends to produce soft pork, the greater the amount of corn which is fed the harder the meat will be at the end of the grazing period. Soybeans are often grown with corn and the combined crop hogged down. (358)

990. Cowpea pasture.—Especially on poorer soils in the southern states the cowpea is an important forage crop for swine, as it flourishes where other legumes will not produce good crops. In a 60-day trial by Gray, Summers, and Shook[97] in Alabama with 3 lots, each of five 53-lb. pigs, the following results were secured:

Cowpea pasture for fattening pigs

Average ration	Daily gain	Feed for 100 lbs. gain Concentrates	Pasture
	Lbs.	Lbs.	Acres
Lot I, Corn, 2.62 lbs. Tankage, 0.29 lb.	0.54	540	....
Lot II, Corn, 1.39 lbs. Tankage, 0.16 lb. Cowpea pasture	0.97	159	0.78
Lot III, Corn, 1.56 lbs. Cowpea pasture	0.90	173	0.83

The pigs on cowpea pasture gained nearly twice as fast as those fed corn and tankage without pasturage. The pigs were grazed on a good crop of cowpeas from August 12 to September 16, but from this date to November 5 they were grazed on a field in which there was only half a normal crop, hence the large area of pasture required per 100 lbs. of gain. On land suited to soybeans they excel cowpeas for pigs on account of the larger production of seed. Like soybeans, cowpeas and corn are frequently hogged down. (357)

991. Velvet bean pasture.—To determine the value of velvet bean pasture for pigs, Gray, Summers, and Shook[98] turned a lot of five 62-lb. grade pigs into a field where velvet beans had been grown with corn, but the corn crop already removed. In addition the pigs were given a half ration of corn meal 9 parts, and tankage 1 part, while another lot was fed corn and tankage in a dry lot. During 72 days the pigs foraging the velvet beans gained 1.23 lbs. per head daily, requiring 0.38 acre of beans and only 170 lbs. of concentrates for 100 lbs. gain. The pigs in the dry lot gained but 0.84 lb. and consumed 400 lbs. concentrates for 100 lbs. gain. An acre of velvet beans, raised in a corn field, thus replaced over 600 lbs. of concentrates. Velvet beans in the pod may also

[97] Ala. Bul. 168.

[98] Ala. Bul. 168.

be fed to pigs as a supplement to corn or other grain. The pigs will not eat the pods, but become expert in shelling out the beans.[99] (361)

992. Rape pasture.—Over the greater part of the northern United States rape is unsurpassed as an annual forage crop for swine. As it may be sown both early and late in the season, forage may be provided at any desired time. The best yields are usually obtained with spring seeding and if the crop is not pastured too closely growth will continue until fall. According to Evvard of the Iowa Station,[100] the pigs should not be turned on the rape till it is 10 to 14 inches high and when it is pastured down to 4 or 5 leaves to the plant the animals should be transferred to another plot to give the crop a chance to recuperate. The value of rape pasture for pigs is well shown in the following summary of 6 trials, lasting 80 to 190 days, in which one lot of spring pigs was pastured on rape and another on alfalfa, both being fed concentrates in addition:

Rape vs. alfalfa pasture for pigs

Average ration		Daily gain	Concentrates for 100 lbs. gain
		Lbs.	Lbs.
Lot I,* Concentrates, 3.7 lbs.	Rape pasture	1.08	340
Lot II,* Concentrates, 3.8 lbs.	Alfalfa pasture	1.12	344

*Average of 3 trials by Evvard (Iowa Bul. 136, Proc. Am. Soc. Anim. Prod. 1913), 1 by Otis (Kan. Bul. 99), and 2 by Waters, Kinzer, Wheeler, and King (Kan. Bul. 192).

The pigs on rape pasture made practically as large gains as those on alfalfa pasture and required even less concentrates for 100 lbs. gain. Where alfalfa thrives it surpasses rape, not because it results in larger gain, but because it will usually carry more pigs per acre and does not need to be reseeded each year. In 2 of the Kansas trials an acre of alfalfa pasture carried twice as many pigs thruout the season as did an acre of rape. In 2 of the Iowa trials, however, rape produced more pork per acre than did alfalfa. Evvard[101] finds that the portion of the rape plant eaten by pigs is nearly as rich in protein, on the dry matter basis, as is alfalfa, and that pigs fed corn on rape pasture do not need the addition of more than 5 per ct. of tankage, or an equivalent amount of other supplement, to the corn allowance. Pigs with light colored skin or thin hair may be blistered by running in rape when the dew is on, but this may be obviated by keeping them off the fields at such times.

Rape is often grown in combination with oats or oats and field peas for pig pasture. From trials at the Missouri Station[102] Mumford and Weaver rank rape and oats next to alfalfa and red clover among several forage crops tested. At the Wisconsin Station[103] Carlyle found rape fully equal to red clover pasture, an acre of rape grazed by pigs 4 to 10 months old replacing 2,436 lbs. of mixed corn meal and wheat shorts. At the Oregon Station[104] an acre of rape pasture with no grain pro-

[99] Scott, Fla. Bul. 113.
[100] Iowa Bul. 136.
[101] Iowa Bul. 136.
[102] Mo. Bul. 110.
[103] Wis. Rpt. 1901.
[104] Ore. Bul. 89.

duced 154 lbs. of gain with pigs. Grisdale of the Ottawa Experimental Farms[105] pastured 60 pigs that finally reached an average weight of 185 lbs. each, on 1.5 acres of rape, feeding in addition thereto about 500 lbs. of grain to each pig. Rape is an excellent winter forage crop for the South. In 2 trials at the Alabama Station[106] Gray, Summers, and Shook found that pigs, weighing from 45 to 60 lbs., fed a half allowance of corn and either shorts or tankage on rape pasture for 116 to 147 days during the winter, made an average daily gain of 0.70 lb. and required 0.14 acre of rape and only 273 lbs. of concentrates for 100 lbs. of gain. **(381)**

993. Grasses and cereals for pasture.—Among the permanent grasses bluegrass provides the best pasture thruout the northern states. As bluegrass makes little growth during midsummer, other crops should be provided for this season, the bluegrass being relied on for grazing in spring and early summer and in early fall. With pigs fed corn on bluegrass, a somewhat larger allowance of nitrogenous supplement is needed than on legume or rape pasture, tho very young bluegrass is fairly rich in protein. **(310-11)** In the South, Bermuda grass furnishes the best permanent grass pasture for pigs. **(320)**

For fall and early spring pasture in the North and for pasture from late fall thruout the winter and spring in the South, the cereals are unexcelled. Good of the Kentucky Station[107] has found that green rye, wheat, or oats when 5 to 8 inches high are even richer than alfalfa, clover, soybeans, or cowpeas in protein. Hence the cereals at this stage are really nitrogenous pastures, and go far toward supplementing corn. Good conducted 3 trials, averaging 117 days, to determine the value of giving a small allowance of tankage or soybeans to 49-lb. pigs fed corn on rye pasture during the winter and spring, securing the results shown in the table:

Feeding supplement with corn to pigs on rye pasture

Average concentrate allowance	Daily gain	Concentrates for 100 lbs. gain
	Lbs.	Lbs.
Lot I, Corn, 3.0 lbs.	0.74	397
Lot II, Corn, 2.8 lbs. Supplement, 0.39 lb.	0.92	345

The pigs fed a small amount of supplement with the corn made larger and more economical gains than those fed only corn on the rye pasture. During the periods when the pasture is covered by snow it is especially advantageous to feed a supplement with the corn. In the southern states, winter rye or oats will furnish most satisfactory pasture for pigs thruout the entire winter, greatly decreasing the cost of maintaining brood sows and raising fall pigs. **(318)**

994. Hogging down ripe grain.—Ripe grain, usually rye, bald barley, or wheat, is frequently hogged down, the pigs being turned into the field

[105] Ottawa Expt. Farms, Bul. 51. [106] Ala. Bul. 168. [107] Ky. Bul. 175.

when the crop is nearly ripe. This practice is especially common in the grain districts of the Pacific Northwest, where the summers are dry. Hunter of the United States Department of Agriculture[108] reports that in eastern Washington 109 pigs having access to an acre of pasture hogged down 7.2 acres of standing wheat, and gave a net return of $15.73 per acre. The net return from wheat alongside, harvested and threshed, was only $8.04 per acre. In 5 trials by Mumford and Weaver at the Missouri Station[109] ripe rye hogged down produced an average of 212 lbs. of pork per acre, after deducting the additional grain fed. In a trial by Evvard at the Iowa Station[110] a crop of rye yielding 41 bushels per acre was worth only $3.89 an acre when hogged down by pigs fed meat meal in addition, with pigs selling at $6.00. Later when hogging down corn the same pigs made most satisfactory gains. It seems doubtful whether it is usually profitable to hog down the small grains in the humid districts, when labor can be secured to harvest the crop. As we have seen (**942**), hogging down corn is a most successful practice.

995. Gleaning stubble fields.—Especially on the grain farms of the West stubble fields are an important factor in economical pork production. Where the grain is harvested by means of a header a considerable amount is left ungarnered and was formerly wasted. Now many farmers are hog fencing their fields and turning pigs on the stubble to glean the scattered heads of grain. Gains made on such waste are almost clear profit.

996. Sorghum; Japanese cane.—Sorghum is too high in fiber to excel as a pasture for young pigs, tho it is useful in the South for providing succulence when other crops are not available. For older pigs it gives somewhat better results,[111] supplied in addition to a fair allowance of grain. (**309**)

Scott found at the Florida Station[112] that Japanese cane fed alone would not maintain young pigs. As succulence with grain this forage should have about the same value as sorghum. (**323**)

997. Soilage.—It is not ordinarily profitable to cut and haul green crops to pigs, for they can better do their own harvesting. To determine the value of soilage as a supplement to corn, Waters fed 4 lots, each of six 48-lb. pigs, the rations shown in the table for 102 days at the Missouri Station.[113] The fresh-cut green forage was fed twice daily.

Various soilage crops compared

Average ration	Daily gain	Feed for 100 lbs. gain Concentrates	Feed for 100 lbs. gain Soilage
	Lbs.	Lbs.	Lbs.
Lot I, Middlings, 1.4 lbs. Corn meal, 2.1 lbs....	0.7	518	...
Lot II, Green alfalfa, 0.8 lb. Corn meal, 3.3 lbs.	0.8	401	91
Lot III, Green clover, 0.7 lb. Corn meal, 3.3 lbs..	0.8	435	93
Lot IV, Green bluegrass, 0.7 lb. Corn meal, 3.4 lbs.	0.6	531	113

[108] U. S. Dept. Agr., Farmers' Bul. 599. [109] Mo. Bul. 110. [110] Iowa Bul. 136.
[111] Gray, Duggar, and Ridgeway, Ala. Bul. 143; Scott, Fla. Bul. 113.
[112] Fla. Bul. 113. [113] Mo. Bul. 79.

The pigs fed green alfalfa or clover made larger gains than those fed middlings and corn meal, 78 lbs. of green alfalfa or 112 lbs. of green clover saving 100 lbs. of concentrates. Bluegrass was a poor supplement to corn. (**418-22**)

998. Roots.—We have seen in previous chapters that for dairy cattle, beef cattle, and sheep, silage from corn or the sorghums provides about as satisfactory succulent feed as do roots, and at a much lower cost over the greater part of our country. (**366, 638-40, 784, 866**) With the pig however, silage will not replace roots, for the digestive apparatus of this animal is not adapted to utilize large amounts of such coarse and fibrous feed. Since roots have a high value for pigs, with the high prices now ruling for concentrates large numbers of farmers can profitably grow roots for winter succulence for their pigs. Roots not only add variety to the ration, but reduce the amount of concentrates required, and aid in maintaining the health of the animals. On account of their slightly laxative effect and their bulkiness, roots are especially valuable for brood sows in winter. Danish farmers grow no Indian corn, and yet by means of waste products of the dairy, purchased feeding stuffs, and root crops, mostly beets, they lead the world in the production of pork, both as to quantity and quality.

The value of roots for fattening pigs is shown in the following table, summarizing the results of 8 trials, averaging 88 days, in which concentrates alone were fed to one lot of pigs, while another lot was fed roots in addition to the same concentrates:

Value of roots for fattening pigs

Average ration	Initial weight	Daily gain	Feed for 100 lbs. gain	
			Concentrates	Roots
	Lbs.	Lbs.	Lbs.	Lbs.
*Lot I, total of 38 pigs**				
Concentrates, 5.4 lbs.	90	1.2	499	...
*Lot II, total of 38 pigs**				
Concentrates, 3.6 lbs. Roots, 5.6 lbs.	87	1.0	358	631

*Average of 1 trial by Clark (Utah Bul. 101), 1 by Lazenby (Ohio Rpt., 1884), 2 by Plumb (Ind. Buls. 79, 82), 1 by Robertson (Ottawa Expt. Farms, Rpt. 1891), 2 by Sanborn (Utah Rpt. 1891), and 1 by Shaw (Mont. Bul. 27).

As shown in the table, the value of adding roots to the ration for fattening pigs, lies not in any increase in the rate of gain, but in lessening the amount of concentrates required for 100 lbs. gain. In these trials only 448 lbs. of roots was required to save 100 lbs. of concentrates. This is a higher value than we would expect from the amount of dry matter they contain, for 100 lbs. of corn contains as much dry matter as 546 lbs. of sugar beets, which are the richest of the common root crops. The high value of roots is undoubtedly due to their beneficial effect on the digestive tract. For young pigs roots are especially valuable, as they tend to growth rather than fattening. Indeed, in finishing pigs the allowance of roots should be restricted, or the desired finish will not be secured.

Root crops may be economically gathered by turning pigs in to graze the field. At the Michigan Station,[114] Shaw turned pigs receiving one-third of a normal grain ration into a beet field to do their own foraging and found that 1 acre of sugar beets produced 716 lbs. and 1 acre of half sugar beets and half mangels 792 lbs. of gain. In the South root crops may be used with advantage as forage for pigs during the winter.

Tho it is not wise to force pigs to live on roots alone, it is of interest to note that Buffum and Griffith of the Colorado Station[115] found that sugar beets, fed alone, rather more than maintained pigs. As high as 25 lbs. per day of mangels have been fed to dry sows or those not far advanced in pregnancy, the allowance being decreased and the meal ration somewhat increased as pregnancy advanced.

999. Comparison of root crops.—The Danish (Copenhagen) Experiment Station,[116] in trials with 204 pigs fed whole or sliced roots in combination with skim milk, whey, and grain, found that 1 lb. of ground barley was equal in feeding value to:

	Dry matter	Sugar
7.5 lbs. mangel beets containing........	11.0 per ct.	6.7 per ct.
6.5 lbs. mangel beets containing........	13.6 per ct.	8.9 per ct.
5.0 lbs. fodder beets containing........	16.5 per ct.	10.9 per ct.
4.0 lbs. sugar beets containing........	21.2 per ct.	14.0 per ct.

Thus it is shown that 7.5 lbs. of mangels or 4 lbs. of sugar beets are as useful in pig feeding as 1 lb. of ground barley, when all are combined with dairy waste products. Carrots proved as valuable as beets when measured by the dry substance contained. Since roots are almost wholly digestible their relative feeding value depends upon the total dry matter they contain, rather than the variety or kind. According to Day,[117] sugar beets not only possess the highest feeding value per ton, but are also most readily eaten by pigs. He states that hogs prefer mangels to carrots. (**367-72**)

1000. Sugar beets; beet pulp; molasses.—At the Utah Station[118] Clark fed sugar beets, wet beet pulp, and beet molasses in combination with wheat shorts to 4 lots of 130-lb. pigs for 48 days with the results shown below:

Sugar beets, beet pulp, and beet molasses fed to pigs

Average ration		Daily gain	Feed for 100 lbs. gain		
			Shorts	Beets or beet pulp	Molasses
		Lbs.	Lbs.	Lbs.	Lbs.
Lot I					
Shorts, 7.6 lbs......................		1.7	444	....	...
Lot II					
Shorts, 3.2 lbs.	Sugar beets, 8.3 lbs...	1.2	268	697	...
Lot III					
Shorts, 3.3 lbs.	Beet pulp, 12.3 lbs....	1.2	275	1,030	...
Lot IV					
Shorts, 3.0 lbs.	Beet pulp, 9.4 lbs. Beet molasses, 4.4 lbs.	1.6	186	600	281

[114] Mich. Bul. 233.
[115] Colo. Bul. 74.
[116] Copenhagen (Denmark) Station, Rpt. 1892.
[117] Productive Swine Husbandry, p. 206.
[118] Utah Bul. 101.

The table shows that while the shorts-fed pigs gained 1.7 lbs. each daily, those fed a half allowance of shorts with sugar beets or beet pulp additional gained 1.2 lbs. each daily. In this trial 609 lbs. of wet beet pulp or 396 lbs. of sugar beets replaced 100 lbs. of wheat shorts. (**274**) Shorts, beet pulp, and beet molasses combined produced nearly as large gains as shorts alone. One hundred lbs. of beet molasses saved 32 lbs. of shorts and 153 lbs. of beet pulp. All the pork was of good quality except that from the molasses-fed pigs, which had a peculiar unsavory taste. (**276**)

Overfeeding with beet molasses causes pigs to scour. In a trial at the New York (Cornell) Station,[119] after feeding five 87-lb. pigs a ration of 1.6 lbs. corn meal, 2.4 lbs. sugar-beet molasses, and 4 lbs. milk for 3 days, 2 pigs died suddenly. The molasses was then withdrawn from the ration, but the remaining pigs did not thrive, doubtless due to the effects of the molasses.

1001. Potatoes.—In two trials by the senior author at the Wisconsin Station[120] potatoes were cooked in an open kettle, using as little water as possible, and corn meal added to form a thick mush which was eaten by pigs with great relish. Corn meal wet with water was fed to a second lot for comparison. The results were as follows:

440 lbs. of corn meal, fed alone, produced 100 lbs. of gain.
262 lbs. of corn meal with 786 lbs. of potatoes, weighed before cooking, produced 100 lbs. of gain.

From this we learn that 786 lbs. of potatoes, when fed to pigs after being cooked, effected a saving of 178 lbs. of corn meal, 442 lbs. of potatoes taking the place of 100 lbs. of corn meal.

At the Copenhagen (Denmark) Station[121] Fjord found 400 lbs. of cooked potatoes equal to 100 lbs. of mixed grains for swine.

Potter of the Oregon Station[122] reports that when steamed potatoes were fed with barley at the rate of 3 to 6 lbs. of potatoes to 1 lb. of barley, it took only 340 to 381 lbs. of potatoes to replace 100 lbs. of grain. To replace 100 lbs. of barley 552 lbs. of raw potatoes were required. Grisdale of the Ottawa Experimental Farms[123] reports that raw potatoes alone will scarcely maintain life in pigs, but given in small quantities they help to keep them in health when other succulent feed is lacking. (**374**) Potatoes should be cooked for pigs, and fed with concentrates.

1002. Artichokes.—French of the Oregon Station[124] placed pigs in a field of artichokes, estimated to yield 740 bu. per acre. As the pigs made little gain on the tubers alone, a small allowance of mixed wheat and oats was supplied in addition, about 310 lbs. of mixed grain being then required to produce 100 lbs. of gain. In this case the artichokes saved from 150 to 200 lbs. of grain for each 100 lbs. of gain made.

[119] N. Y. (Cornell) Bul. 199.
[120] Wis. Rpt. 1890.
[121] Copenhagen (Denmark) Station, Rpt. 1890.
[122] Breeder's Gaz., 63, 1913, p. 896.
[123] Ottawa Expt. Farms, Bul. 57.
[124] Ore. Bul. 54.

Sweitzer of the Missouri Station[125] rates artichokes equal to potatoes for pig feeding. Grisdale of the Ottawa Experimental Farms[126] found artichokes economical and slightly more valuable than potatoes. Altho long grown in a small way and often extolled, no extended feeding trials have yet been made with artichokes, nor does their use by feeders seem to increase. (**375**)

1003. Pumpkins; squashes.—Rommel,[127] summarizing the findings of 3 stations, reports that 273 lbs. of grain, together with 376 lbs. of raw pumpkins, gave 100 lbs. of gain with fattening pigs. When cooked it required 1,150 lbs. of pumpkins and 222 of grain for 100 lbs. of gain. From these data we may conclude that cooking is of no advantage with this vegetable. As has been pointed out before (**383**), the seeds should not be removed before feeding pumpkins as they are rich in nutrients. Feeding an undue allowance of seeds would, however, tend to cause digestive disturbance, on account of their richness.

Cottrell of the Colorado Station[128] states that some Colorado stockmen fatten hogs exclusively on raw squashes. They report favorable returns per acre, with meat of good flavor but having an undesirable yellow color.

1004. Sweet potatoes.—Dodson of the Louisiana Station[129] recommends sweet potatoes as the best root crop for pigs for fall and early winter grazing on the cut-over pine lands of the South. Sweet potatoes planted in June and early July are ready for feeding by the middle of October. Since the tubers are low in protein, pigs grazing sweet potatoes should be given such nitrogenous feeds as soybeans or cowpeas. Dodson states that an acre of sweet potatoes should carry 8 to 10 year-old pigs for 60 days, when they are given a limited concentrate allowance in addition. Duggar of the Alabama Station,[130] allowing pigs to harvest sweet potatoes at will, secured 100 lbs. of gain by feeding 313 lbs. of grain additional, thereby saving about 200 lbs. of grain for each 100 lbs. of increase while fattening. (**376**)

1005. Peanuts.—For the season in the fall when they are available peanuts provide one of the best forage crops for pigs in the South. Their value is shown in a trial by Gray, Summers, and Shook at the Alabama Station,[131] in which 3 lots, each of six 60-lb. pigs, were fed for 96 days as shown in the table:

Peanuts as a forage crop for pigs in the South

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Pasture Acres
Lot I, Peanut pasture only	1.00	...	0.22
Lot II, Corn, 1.7 lbs. Peanut pasture	1.25	134	0.18
Lot III, Corn, 1.6 lbs. Tankage, 0.4 lb. Pasture	1.42	139	0.13

The pigs on peanut pasture without other feed made fair gains but

[125] Mo. Bul. 29.
[126] Ottawa Expt. Farms, Bul. 51.
[127] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 47.
[128] Colo. Bul. 146.
[129] La. Bul. 124.
[130] Ala. Bul. 122.
[131] Ala. Bul. 168.

were not fat enough for market at the close of the trial, while Lots II and III were well finished. Compared with another lot fed corn and tankage in a dry lot, an acre of peanut pasture saved 2,390 lbs. of concentrates. Lot I, grazing peanuts alone, made 454 lbs. of gain per acre of peanuts. Much higher returns than this are sometimes secured, a field at the Arkansas Station yielding at the rate of 1,252 lbs. of pork per acre. Since peanuts tend to make soft pork, pigs should be finished on such feeds as corn for at least 2 to 3 weeks after grazing peanuts. Peanuts can be grazed during only a relatively short season, for after a time the nuts will sprout or rot if left in the ground, especially in wet weather. **(258, 362)**

1006. Chufas.—Like artichokes, the small tubers of the chufa remain in the ground uninjured all winter. Chufas grow best on light, sandy soils, producing 100 to 150 bushels per acre. Duggar of the Alabama Station[132] hurdled young pigs on a chufa field, giving them corn and cowpea meal additional. The average of 2 trials showed that, after due allowance was made for the grain fed, the chufas produced pork at the rate of 307 lbs., worth over $15 per acre. **(377)**

1007. Cassava.—Conner of the Florida Station[133] found that pigs fed cassava alone or equal parts of cassava and sweet potatoes did not maintain their weight. When fed with shorts cassava produced fair gains. Larger returns can generally be secured from other crops for pigs than from cassava. **(378)**

1008. Silage.—May of the Kentucky Station[134] found that hogs receiving shelled corn and corn-and-soybean silage made larger gains than those fed shelled corn alone, 100 lbs. of silage equaling 22 lbs. of corn in feeding value. The pigs first picked out the grain in the silage and then chewed the remainder, tho swallowing but little of it. At the Ottawa Experimental Farms[135] clover and alfalfa silage invariably proved useful, and corn silage was fairly well eaten. The addition of some dry meal to the silage caused it to be eaten quite readily. Clover, alfalfa, or other legume hay should generally prove more satisfactory than silage of any kind. Silage from the corn plant is both too woody and too low in digestible matter to serve with any satisfaction as a feed for swine that are being properly maintained. If shotes and breeding stock live on a limited allowance of rich concentrates alone, they will suffer for lack of proper bulk in the ration. For such pigs, silage, and even corn silage, will be helpful in distending the digestive tract.

1009. The legume hays.—With the prices of feeding stuffs ruling high, the swine feeder must make the largest possible use of alfalfa, clover, vetch, cowpea, soybean, and other legume pasture in summer, and in winter feed freely of specially cured hay from the legumes in order to have healthy animals and to keep down the cost of production. The finer parts of clover and alfalfa hay, especially the first cutting of clover and

[132] Ala. Bul. 122.
[133] Fla. Bul. 90.
[134] Ky. Bul. 101.
[135] Ottawa Expt. Farms, Bul. 51.

the last cutting of alfalfa, are often as valuable for feeding pigs as is the same weight of expensive wheat middlings. The southern planter has a specially choice list of equally valuable legumes in the cowpea, soybean, velvet bean, peanut, etc. Legume hay may be fed to pigs from slatted racks or from boxes with openings low on the sides from which the animals can eat at will. The legume hays not only furnish protein, so essential for building all the lean meat tissues and the organs of the body, but they also carry much calcium (lime), which is needed in bone building. They are therefore doubly useful in supplementing Indian corn and the other cereals, which are rather poor in both protein and calcium.

1010. Alfalfa hay.—Leafy, bright alfalfa hay is the best of all legume hays for the pig. Not only is this hay useful for brood sows and stock pigs but it is a cheap and fairly efficient supplement to corn or the other cereals for fattening pigs. The value of alfalfa hay for fattening pigs is shown in the following table, which summarizes the results of 3 trials, averaging 103 days in length, by Snyder at the North Platte, Nebraska, Substation,[136] with pigs averaging 133 lbs. in weight:

Alfalfa hay for fattening pigs

Feed given	Daily gain	Corn for 100 lbs. gain	Feed cost of 100 lbs. gain*
	Lbs.	Lbs.	Dollars
Lot I, Corn alone	1.27	506	4.25
Lot II, Corn and long alfalfa hay in rack	1.50	436	3.78
Lot III, Corn 90, and chopped alfalfa hay 10 per ct.	1.46	433	3.87
Lot IV, Corn 75, and chopped alfalfa hay 25 per ct.	1.12	431	4.33
Lot V, Corn 75, and alfalfa meal 25 per ct.	1.27	399	4.35

*Corn at $0.47 per bushel; long alfalfa hay at $8, chopped alfalfa hay at $10, and alfalfa meal at $15 per ton.

In these trials the pigs in Lot I, fed ground corn alone, made better gains than is usual on this unbalanced ration, due to the fact that they had been well-grown on alfalfa pasture. The pigs in Lot II, supplied long alfalfa hay in racks in addition to corn, gained 0.23 lb. more per head daily than those in Lot I and made the largest and the cheapest gains of all lots. Chopping the hay by passing it thru a feed cutter or grinding it to a meal did not produce more rapid gains, but increased the cost. When the proportion of cut alfalfa hay or alfalfa meal was increased to 25 per ct. the gains were smaller and more expensive. In trials at the Kansas Station,[137] Kinzer and Wheeler likewise found that grinding alfalfa hay to meal did not result in larger gains by fattening pigs.

While fattening cattle and sheep will consume enough alfalfa hay to make a fairly well balanced ration with corn, the fattening pig has not this capacity for roughage and hence will not consume enough hay to balance his ration sufficiently to produce maximum gains. This is shown in 4 trials by Waters, Kinzer, and colleagues at the Kansas Station[138]

[136]Nebr. Bul. 124. [137]Kan. Bul. 192. [138]Kan. Bul. 192.

with a total of 192 pigs, in which one lot was fed corn with alfalfa hay in racks while another was fed corn and tankage. The results of the trials, which averaged 65 days, are summarized in the table:

Alfalfa hay vs. tankage as supplements to corn

Average ration		Initial weight	Daily gain	Feed for 100 lbs. gain Concentrates	Hay
		Lbs.	Lbs.	Lbs.	Lbs.
Lot I, Corn, 6.5 lbs.	Alfalfa hay, 1.2 lbs.	154	1.13	587	95
Lot II, Corn, 6.6 lbs.	Tankage, 0.9 lb....	153	1.58	477	..

Lot II, fed tankage and corn, made considerably larger gains than Lot I, fed alfalfa hay as the sole supplement to corn. With corn at $19, alfalfa hay at $8, and tankage at $41 to $45 per ton, in each trial the gains of Lot I were more expensive than where tankage was used as the supplement.

Whether to use alfalfa hay or purchased concentrates to balance the ration of the fattening pig will depend on the relative price of these feeds. With corn and barley at $20, tankage at $40, and alfalfa hay at $5 per ton, Morton of the Colorado Station[139] found alfalfa a much more economical supplement than tankage. In one trial by Snyder at the North Platte, Nebraska, Substation,[140] fattening pigs made cheaper gains and returned more profit on corn and alfalfa hay than on corn and 5 per ct. of tankage, while in another trial the results were reversed. Snyder points out that alfalfa hay is most efficient as a supplement in fine winter weather when the pigs have good appetites for the hay and corn. In unfavorable weather or when the pigs are out of condition the use of some nitrogenous concentrate, like tankage, linseed meal, or shorts, aids in stimulating the appetite and hence results in larger gains. **(339, 1013)**

1011. Clover hay.—In 2 trials with 90-lb. pigs at the Montana Station[141] Linfield found that pigs fed 4.9 lbs. per head daily of a mixture of 2 parts ground barley and 1 part wheat bran gained 0.9 lb. per head daily, requiring 529 lbs. of concentrates for 100 lbs. of gain. Other lots fed the same concentrate allowance with 1 lb. of clover hay per head daily made an average daily gain of 1 lb. and required 487 lbs. of concentrates and 101 lbs. of hay for 100 lbs. of gain. In these trials 100 lbs. of clover hay was equal to 42 lbs. of mixed barley and bran. **(347)**

[139]Colo. Bul. 188. [140]Nebr. Bul. 147. [141]Mont. Bul. 57.

CHAPTER XXXV

FEED AND CARE OF SWINE

Tho the synonym for filthiness, no other animal serving man will, if given a chance, so well keep its abode in order as the pig. He will industriously gather dried grass, leaves, etc., and form them into a bed which he will not foul. The floor where his corn is thrown will remain clean if he has half a chance to show his manners. When he wallows in the mire or rubs on the oiler it is with a wisdom that knows whereof it acts.

He is excelled only by the cow in economy of converting the gross products of the farm into edible products for man. Garbage, vegetable and other waste, green forage, and grain are all voraciously consumed and quickly and economically converted into meat. So swift is his career that he usually breaks into life with the spring flowers, plays the gormand in summer, and yields his unctuous body a sacrifice to men's necessities with the dropping of the leaves in fall. The pig is the poor man's reliance and the opulent farmer's gold mine. Of all domestic animals he is the most prolific, and his possibilities in multiplying are the delight of the city man in his ecstatic dreams of land owning and raising his meager investment in a single mother pig to the *n*th power thru her precocious progeny.

1012. Summer care of swine.—During summer all swine, including brood sows and boars, should live in the open air on fresh, uncontaminated soil in order to escape intestinal parasites and other ailments. Grazing on succulent pastures with a reasonable allowance of concentrates additional, they will develop bone, muscle and constitution along with a vigorous, roomy, digestive tract. Shade and running water, preferably supplied from a well, or, if from a spring or brook, safeguarded from contamination, are essential in pastures. Artificial wallows, made of cement, that hold a few inches of water, will not spread disease, afford much comfort, and are a paying proposition when many pigs are kept.

Tho even mature pigs can barely subsist on grass pasture, good pasture, such as alfalfa, clover, or rape, somewhat more than sustains life and so leaves for producing increase all the extra feed which may be supplied. In addition to pasture, sufficient concentrates should be fed to keep the pigs thrifty and gaining, but in no case so abundantly as to make them lazy and shiftless, for pigs, if heavily fed, forage little, but lie idly in the shade. Observation will soon determine the quantity of feed which will keep pigs gaining normally while actively foraging to appease their hunger. With animals on such protein-rich pasture as that furnished by the legumes and rape, the concentrates may be mostly carbonaceous in character, such as corn, wheat, barley, kafir, and milo, with enough skim milk, tankage, wheat middlings, linseed meal, or other protein-rich concentrates to balance the ration. (**918, 964**)

Boars and brood sows of the larger breeds should reach a weight of about 250 lbs. at one year of age if rightly fed and managed. The feed and care of the boar does not differ from that of the sow. Too often both are closely confined in filthy quarters, away from the wholesome earth, without opportunity for exercise or foraging.

1013. Winter feed and care.—Breeding stock and shotes should not be heavily fed during winter lest they grow too fat. If rich concentrates only are given and the animals not overfed, the feed allowance will not have enough volume or bulk to distend the stomach and intestines properly, and this leaves the animals unsatisfied, restless, and quarrelsome. To correct this trouble and because such feed is both cheap and wholesome, all such hogs should be daily fed some fine, well-cured legume hay or some roots, or better, both hay and roots. If, unfortunately, neither is available, then bran and oats, tho more costly, will be helpful in giving bulk to the ration. The concentrates fed to stock hogs should always be given as a thin, watery slop with the chill taken off, to help distend the digestive tract at meal time.

Pigs that do not otherwise get exercise in winter should be provided with a feeding floor, covered, if possible, and kept clean, on which shelled corn and whole oats are scattered thinly so as to force them to pick up a grain at a time. Here too can be placed racks holding legume hay. In this way pigs may be kept out of their beds and on their feet for hours at a time getting air and exercise. Young breeding stock and shotes should gain from half to three-fourths of a pound daily in winter, the supply of feed being regulated to that end.

It is highly important that the ration of the brood sow furnish ample protein and mineral matter for the proper nourishment of her body and the development of the unborn young. Trials by Evvard of the Iowa Station,[1] which are summarized in the following table, show the folly of feeding brood sows corn alone. In one trial a lot of 5 gilts was fed 3.6 lbs. of ear corn alone per head daily, while other lots were fed ear corn and meat meal; ear corn and a mixture of oats, wheat bran, wheat middlings, and linseed meal; shelled corn with cut clover hay and molasses; ear corn and clover hay; and ear corn and alfalfa hay. In a similar trial with 4 lots, each of 10 yearling sows, one lot was fed ear corn alone, and the other lots ear corn supplemented by meat meal, linseed meal, or alfalfa hay. In the table all weights of ear corn are reduced to a shelled corn basis.

[1] Proc. Am. Soc. Anim. Prod., 1913.

Corn requires supplement for brood sows

Average ration	Daily gain Lbs.	Average weight of pigs Lbs.	Proportion of strong pigs Per ct.
Gilts, 5 in each lot			
I, Ear corn, 3.6 lbs	0.35	1.74	68
II, Ear corn, 3.2 lbs. Meat meal, 0.13 lb	0.58	2.01	93
III, Ear corn, 2.8 lbs. Meat meal, 0.43 lb	0.62	2.23	93
IV, Ear corn, 2.7 lbs. Mixture (oats 3, bran 3, middlings 3, linseed meal 2 parts), 1.1 lbs	0.35	1.84	83
V, Shelled corn, 3.8 lbs. Cut clover and molasses, 1.6 lbs	0.58	2.19	86
VI, Ear corn, 3.7 lbs. Clover hay in rack, 0.30 lb	0.53	2.21	94
VII, Ear corn, 3.7 lbs. Alfalfa hay in rack 1.1 lbs	0.63	2.29	89
Yearling sows, 10 in each lot			
I, Ear corn, 5.0 lbs	0.59	1.85	41
II, Ear corn, 4.1 lbs. Meat meal, 0.50 lb	0.78	2.42	85
III, Ear corn, 4.1 lbs. Linseed meal, 1.1 lbs	0.67	2.22	76
IV, Ear corn, 5.0 lbs. Alfalfa hay in rack, 0.27 lb	0.64	1.77	37

Both the gilts and the yearling sows fed corn alone farrowed pigs lighter in weight and less vigorous than when the ration was properly balanced. Lot IV of the yearling sows ate so little alfalfa hay that it was insufficient to balance the corn allowance, as is shown by the weight of the pigs farrowed and the low percentage of strong pigs. The gilts fed clover or alfalfa hay made good gains and farrowed large, strong pigs.

In 4 trials at the North Platte, Nebraska, Substation[2] Snyder found that 340-lb. brood sows could be carried thru the winter satisfactorily on 1.1 lbs. of shelled corn daily per 100 lbs. live weight with alfalfa hay supplied in racks, the sows eating 0.70 lb. per head daily. The cost of wintering for these sows was less than when a mixture of half ground corn and half chopped alfalfa was fed.

1014. The brood sow.—The age at which to breed young sows will naturally depend somewhat on the growth they have made. Seldom is it advisable to breed them until they are 8 months old, and many breeders prefer to wait until they are 10 to 12 months old. Whether to raise 1 or 2 litters a year should be determined from local conditions, considering the winter climate and the feeds available. Where winters are long and severe and the sows and pigs can not be given the best of feed and care, it is best not to attempt to raise 2 litters a year. Under the proper conditions, especially where dairy by-products are available, 2 litters a year can be raised successfully even in the northern portion of the country, the spring pigs coming in March or April and the fall pigs in September or early October.

According to Coburn,[3] young sows carry their pigs from 100 to 108 days and old ones from 112 to 115, the average for all being 112 days.

Likely sows that are kindly mothers should be retained for breeders as long as 5 or 6 years if possible. Iddings of the Idaho Station[4] found

[2]Nebr. Bul. 147. [3]Swine in America. [4]Breeder's Gaz., 64, 1913, p. 241.

that gilts bred at 8 months averaged 7.7 pigs per litter; sows 24 months old averaged 9.6 pigs; and aged sows 10.6 pigs per litter. Carlyle[5] found that 4- and 5-yr.-old sows bore 9 pigs to the litter on the average, the litter weighing 26 lbs., while 1-yr.-old sows averaged less than 8 pigs, weighing but 15 lbs. From the records of 1,477 pure-bred sows of 8 breeds Rommel[6] found that on an average there were 9 pigs to the litter, 50.1 per ct. males and 49.9 per ct. females.

Tho young sows have smaller litters than mature sows, they usually raise a larger percentage of their pigs, for they are less clumsy. In trials covering 4 years at the North Platte, Nebraska, Substation,[7] Snyder found that sows with their first litters farrowed 8.2 pigs on the average and raised 6.2 pigs. Old sows farrowed 11.1 pigs on the average, but raised only 6.5.

A sow producing litters of less than 5 should be discarded, while one that can save and raise 8 pigs is a good producer. The pigs in a litter of 8 usually will make larger, more uniform pigs, and in most cases are more profitable to the farmer than abnormally large litters, small in average size and low in vitality.

1015. At farrowing time.—Sows thin in flesh should have their feed gradually increased so as to be in good condition before farrowing. As this period approaches let the feed be both sloppy and limited in amount. Costiveness, common at this time, should be forestalled by feeding wheat bran, linseed oil meal, roots, or the finer parts of some legume hay, and by keeping the animals out of doors and forcing them to exercise. Kennedy[8] reports that in England sows are commonly given from 4 to 5 oz. of epsom salts 2 days before farrowing. Nothing but lukewarm water should be given the sow during the 24 hours previous to farrowing unless she shows signs of hunger, in which case a thin, warm slop containing a little ground oats, wheat middlings, or linseed meal may be supplied. The desire of the sow to eat her young shows abnormal feed or care, or both, for such mothers are usually costive and feverish. When trouble is apprehended Bell[9] recommends feeding about 3 lbs. of salt pork, cut in strips. Harbert would apply mucilage containing equal parts of a tincture of aloes and asafetida to the pigs with a sponge as soon as they are dry. Sows do not like this and let pigs so treated alone. It is far more rational to forestall such possible trouble by enforcing exercise, giving coarse, bulky feeds, and especially in seeing that the bowels move freely so that the sows are not feverish at farrowing time. For 3 or 4 days after farrowing feed lightly with skim milk and oat or barley meal, linseed meal, wheat middlings, or bran in the form of a thin slop, warmed if the weather is cold. A week before farrowing, the sow

[5]Wis. Bul. 104.
[6]U. S. Dept. Agr., Bur. Anim. Indus., Cir. 112.
[7]Nebr. Bul. 147.
[8]U. S. Dept. Agr., Bur. Anim. Indus., Bul. 77.
[9]Breeder's Gaz., 51, 1907, p. 535.

should be placed in the farrowing pen so that she will become accustomed to her surroundings before that event.

The farrowing place should be comfortable, dry, well-ventilated, and so sheltered that a deep nest is not necessary to prevent the new-born pigs being chilled, for they may be crushed in a deep, bird-like nest. Long hay or straw is not suitable for bedding, for it may entangle the pigs. Cut straw or hay, chaff, and leaves are satisfactory, provided they are reasonably free from dust. A plank fastened with the edge against the wall, placed about 8 inches from the floor and standing out 8 inches from the sides of the farrowing pen lessens the danger of the mother crushing her young. In the case of heavy, clumsy sows, separate the pigs from the dam by placing them in a chaff-lined box or barrel for a couple of days. Sows properly handled before farrowing will not usually resent such separation. The pigs will then be safe, and the attendant can pass them to the dam for nourishment at short intervals. A chilled pig may be revived by immersion in water as warm as the hand will bear.

1016. Birth weight of pigs.—In a study by the senior author[10] at the Wisconsin Station each pig in 3 litters as soon as farrowed was tagged and weighed. The new-born pigs weighed from 1.3 to 3.1 lbs. each, the litters aggregating 18.7, 19.2 and 22.5 lbs. each. The first-farrowed pig was neither heavier nor stronger, and the last was neither lighter nor weaker than the others. The so-called "titman," or weakling, found in many litters, is probably such thru lack of food or other extraneous cause, for if given good food and care it not infrequently outgrows its mates.

1017. Care of sow and litter.—Farrowing time over, the ration for the sow should be meager for a day or two, but as the milk flow becomes heavier, should gradually be increased. The coarse feeds, so useful at other times, must now largely give way to rich concentrates, such as skim milk, tankage, heavy flour middlings, ground oats, soybeans, cowpeas, and linseed meal, to furnish nitrogenous matter, and corn, barley, kafir, or milo meal in large proportion to furnish the carbohydrates. Water should be liberally added to form a thin slop. Sows with litters should be liberally fed, for at no other time will feed go so far or give such large returns. (**914**) Good mothers with large litters will usually lose flesh despite the most liberal feeding.

1018. The sow as a milk producer.—Woll[11] found that a sow weighing 438 lbs. gave 7.7 lbs. of milk in 1 day, consuming in that time 4 lbs. of corn meal, 4 lbs. of wheat middlings, and 8 lbs. of skim milk. Such findings show that sows good for breeding purposes rank with good dairy cows in their ability to convert feed into milk. (**543-5**)

At the Wisconsin Station[12] Carlyle studied the milk of 12 sows of 3 breeds. The pigs were kept from the dam except for short periods at 2-hour intervals by day and 4 by night, when they were put with her to suckle. They were weighed collectively before and after that oper-

[10] Wis. Rpt. 1897. [11] Wis. Rpt. 1897. [12] Wis. Bul. 104.

ation, and the increase credited as milk drawn from the dam. With extreme difficulty samples of milk were obtained for analysis. The average yield of milk of 4 sows of each breed during 84 days between farrowing and weaning, determined in the above manner, is given below:

Yield of milk by sows between farrowing and weaning

Breed	Wt. of sow Lbs.	Pigs in litter No.	Av. daily milk yield Lbs.	Av. total milk yield Lbs.
Berkshire	390	7.7	6.3	532
Poland-China	393	7.5	4.9	429
Texas "Razorback"	247	6.3	5.2	434

We learn that these sows gave from 4.9 to 6.3 lbs. of milk daily, the total for 84 days, by which time they went dry, ranging from 429 to 532 lbs. A 4-yr.-old, 532-lb. sow with 10 pigs gave 669 lbs. of milk, while a 5-yr.-old, 490-lb. sow with 8 pigs gave only 337 lbs. Carlyle states that some sows yield almost twice as much milk as others.

1019. Composition of sow's milk.—On analysis the milk of the sows reported in the preceding article showed the composition recorded in the following table:

Average composition of sow's milk

Breed	Fat Per ct.	Casein and albumin Per ct.	Milk Sugar Per ct.	Ash Per ct.	Total solids Per ct.	Specific gravity
Berkshire	7.25	5.74	5.63	0.97	19.59	1.040
Poland-China	6.79	5.94	5.74	0.98	19.19	1.041
Texas "Razorback"	6.64	6.50	5.56	1.01	19.70	1.043

It is shown that in all constituents sow's milk is richer than that of the cow. (**548**) Woll[13] found the fat globules of sow's milk only one-fourth as large as those of cow's milk, but 8 times as numerous. (**550**)

1020. Feeding the litters.—When 2 or 3 weeks old the unweaned pigs should be encouraged to eat with the mother by providing thin, sloppy food in a shallow, low-set trough. Because the sucklings cannot fully satisfy their hunger by such provision, there should be further provided a separate, low trough which cannot be reached by the dam. For young pigs dairy by-products, in combination with various ground grains and milling by-products, are easily the best of all feeds. For very young pigs there is nothing better among the grains than ground oats, with the hulls sieved or floated out, and red dog flour. Corn, barley, kafir, and milo meal, dark feeding flour, flour wheat middlings, and ground emmer with the chaff removed, etc., may all be freely used for sows and pigs as the young things come on. Soaked whole corn thinly scattered over a feeding floor gives feed and enforces exercise. Pigs well fed before weaning grow faster and draw less on the sow—a matter of importance where the litters are large.

Where 1 litter of pigs is raised a year, the pigs may run with their

[13] Wis. Rpt. 1897.

dams 10 or 12 weeks, or the sow may be allowed to wean her pigs herself. However, when 2 litters are to be raised, the pigs must be weaned at the age of about 8 weeks. The sow should be separated from the pigs, and only returned 2 or 3 times long enough for them to empty the udders.

1021. Exercise for young pigs.—Well-nurtured pigs, which often become excessively fat thru liberal feeding and lack of exercise in winter, may die unless forced to take abundant exercise. If sufficient exercise cannot be given, the danger may be averted by reducing the feed supply, but this checks growth. In the absence of more natural exercise the herdsman should turn the pigs out of doors 2 or 3 times a day and drive them about the yard. Selle[14] describes a means for exercising winter pigs as follows: Wagon loads of sods are placed in the cellar in the fall, and in winter these, along with bits of meat scrap or cracklings, are thrown into the pens. In searching for the cracklings the pigs get exercise as well as some feed.

On weaning, pigs of the same size should be placed in groups of not over 20 in order that each and all may receive the care and attention needed. Where large numbers of pigs of varying sizes range together, the weaker ones are at a disadvantage at the feed trough and are liable to permanent injury from lack of feed and rough treatment.

1022. Shotes.—In summer shotes should range the pastures, getting part of their nourishment from succulent alfalfa, clover, vetch, or rape, or, if nothing better is at hand, from the grasses. Green herbage of the proper kind will a little more than maintain the animal, leaving available for growth all the feed supplied. To supplement the pasture 2 lbs. or more of concentrates daily per 100 lbs. live weight should be fed, except where pasture is unusually cheap compared with grain, when no more than 1 lb. per 100 lbs. live weight may be the most economical. (**984**) To force shotes to forage the fields for their entire feed is unwise and expensive. They should gain at least half to three-quarters of a pound per day, and sufficient concentrates to produce this gain should be fed. In winter shotes should be liberally fed the finer parts of some legume hay, such as alfalfa or clover, and roots. These are not only the cheapest of feeds so far as they can be used, but they are helpful in developing a roomy digestive tract capable of utilizing a large amount of feed when the fattening period arrives. Legume hay also furnishes nitrogenous matter and lime, both essentials with these animals. But roughage alone is not sufficient for the growing pig, and therefore such coarse feed should be supplemented with a reasonable supply of rich concentrates containing but little woody fiber. Corn, barley, kafir, milo, and the other cereal grains should be given to furnish heat and lay on fat, while a supply of skim milk, tankage, wheat middlings, soybeans, and other nitrogenous feeds will furnish the protein for muscle building.

1023. The fattening period.—Having developed a strong framework of bone, ample lean-meat tissues, and a roomy, vigorous digestive tract, there now remains the final operation of laying on fat. If the pigs have

[14] Wis. Farmers' Inst., Bul. 1894.

been properly cared for up to this point this is the simplest and easiest part of the whole process. Fattening is best accomplished by restricting the amount of exercise, reducing the allowance of coarse feed, and giving all the palatable carbohydrate-rich concentrates, such as corn, barley, kafir, milo, emmer, etc., the pigs will consume, with sufficient protein-rich feeds to balance the ration. The feeder will gain much help from studying the results secured with the many successful rations fed in trials reviewed in the preceding chapter. Especially during the first part of the fattening period, considerable use can be made of legume hay or forage crops. If the most rapid fattening and the highest finish are desired, as fattening progresses the roughage should be almost entirely eliminated. Even with well-grown shotes, it is important that enough protein-rich feeds be supplied to balance the ration and stimulate the lagging appetite. (**918**) If the fattening period is short, only the small grains need be ground, but if the animals are to be carried to a heavy weight and be highly finished, it may be advisable to grind all grains in order that the consumption of feed may be as large as possible without cloying the appetite. (**920-1**)

If the shotes have been properly brought forward the fattening period should not exceed 8 weeks, unless the animals are to be made unusually fat or there is a rising market which warrants continued feeding. After the first few weeks of heavy feeding more and more feed is required to produce a given gain, and this fact should always be remembered by the feeder. (**913**) All fattening animals should drink water freely, being forced to do so, if necessary, by placing it in their feed. (**926**) At all times coal ashes, wood ashes, lime, etc., should be accessible, as elsewhere recommended. (**927**) Fattening pigs should be fed twice daily, and possibly 3 times toward the close of the period when on ground feed and getting little or no roughage.

Since pigs infested with worms or lice do not make economical gains, the wise feeder will keep his animals free from these pests. When pigs are fed and housed in clean quarters, there should be but little trouble from these sources. Lice may be eradicated by using a dip of crude petroleum or one of the standard stock dips. For intestinal worms various treatments are advised, including turpentine; charcoal and salt; charcoal, wood ashes, and salt; copperas; and lye. From trials at the Iowa Station, Evvard[15] recommends for a 50-lb. pig a dose of 2.5 grains santonin, 1 dram areca nut, 0.5 grain calomel, and 0.5 dram sodium bicarbonate. The amount should be doubled for a 100-lb. pig, increased 3.5 times for a 200-lb. pig, and 5 times as much should be given to one weighing 300 lbs. Feed should be withheld at least 24 hours before giving the remedy, and the dose should be repeated in 8 or 10 days, to be sure that the worms are expelled.

1024. Home markets.—With pork consumption increasing more rapidly than production, there have sprung up over our land good local markets for all manner of pork products, from the dressed carcass to sausages,

[15]Information to the authors.

hams, bacon, etc. Consumers are calling for leaner pork, and many farmers who are feeding pigs will find it to their advantage to supply the home demand for high-grade pork products. Knowledge of how to grow the pig economically on such roughages as the legume hays, roots, and rape is of great value in producing a high-grade product, especially with eastern farmers, who are unable to produce corn as cheaply as it is grown in the corn belt where the lard hog is still the favorite. In finishing pigs for local markets the farmer should study the demand and fatten his animals accordingly, bearing in mind that when the market does not give a premium for the thoroly fat pig it will pay him to save the expensive gains of the last part of the fattening period, which are needed to put on a high finish. (**199, 913**)

American farmers should gain much help from studying the methods of the Danes, who grow no corn, yet lead the world in bacon production. This surprising fact is due to their wise use of dairy by-products, to their spirit of co-operation, and to the high degree of intelligence and skill they show in feeding and caring for their pigs. This knowledge is acquired thru their agricultural colleges and other educational institutions, which are supported and directed by a wise and sympathetic government. The total area of Denmark is but little over one-fourth that of Iowa, yet measured in money this little country exports about one-sixth as much pork products, mostly bacon, as the entire United States.

Most helpfully, local establishments are springing up in this country where pork products of the highest quality are being manufactured, and the success attained by some of these shows that expansion in this direction is possible, as it is also desirable. Since the pig, next to the cow, is the most economical four-footed farm animal for the production of human food, there is every reason to anticipate greatly increased interest in pork production in all the agricultural districts of our country.

APPENDIX

Table I. Average Percentage Composition of American Feeding Stuffs

This table is an exhaustive compilation, made by the authors, of the analyses of feeding stuffs reported by the State Experiment Stations and the United States Department of Agriculture. The preparation of this table and Appendix Tables II and III has required the time of trained assistants equivalent to one person working steadily for three years, in addition to the supervision of the authors. The completeness of the data is evident from the fact that over 53,000 analyses have been gathered into this table. The value of the averages here given is shown by the large number of complete analyses combined for the leading feeding stuffs. For example, 5,335 complete analyses enter into the average for corn meal, 4,641 for standard wheat middlings, 7,742 for wheat bran, etc. Compared with former editions of this book, 270 more averages for different feeds are given, an increase of 80 per ct. When possible separate averages are given for high- and low-grade feeds of the same name, for forage crops at different stages of maturity and with different contents of water, etc. For reasons given in the text, averages for the various proprietary mixed feeds are not here given. (**285**) The figures for a few feeds, for which American analyses are not available, have been taken from *Zusammensetzung der Futtermittel,* by Dietrich and König. Where the scientific names of plants are given in the text, they are not repeated in this table, for they may be readily found by referring to the index. In other instances the scientific names of the plants are here given.

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Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
Concentrates and their By-products	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Corn and its products							
Dent corn	10.5	1.5	10.1	2.0	70.9	5.0	440
Flint corn	12.2	1.5	10.4	1.5	69.4	5.0	52
Soft corn	30.6	1.0	7.4	1.2	56.0	3.8	154
Sweet corn, mature	9.3	1.8	11.5	2.3	67.2	7.9	67
Pop corn	9.4	1.6	12.1	2.0	69.7	5.2	7
Corn meal or chop	11.3	1.3	9.3	2.3	72.0	3.8	5,335
Corn cob	10.0	1.5	2.0	31.8	54.3	0.4	46
Corn-and-cob meal	10.4	1.5	8.5	7.9	67.6	4.1	....
Hominy feed, high grade	10.1	2.6	10.6	4.4	64.3	8.0	778
Hominy feed, low grade	9.1	2.7	9.5	8.5	64.0	6.2	68
Hominy, pearled	10.6	1.2	7.8	1.0	76.1	3.3	5

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
CONCENTRATES—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Corn and its products—con.							
Gluten feed, high grade	8.7	2.1	25.4	7.1	52.9	3.8	800
Gluten feed, low grade	8.8	1.1	17.8	6.9	59.7	5.7	41
Gluten meal, high grade	9.1	1.1	35.5	2.1	47.5	4.7	307
Gluten meal, low grade	8.2	1.5	27.3	9.2	43.4	10.4	52
Germ oil meal, high grade	8.9	2.7	22.6	9.0	46.0	10.8	36
Germ oil meal, low grade	7.8	3.3	13.7	8.7	56.1	10.4	22
Corn bran	10.0	2.4	9.7	9.8	62.4	5.7	77
Wheat and its products							
Wheat, all analyses	10.2	1.9	12.4	2.2	71.2	2.1	858
Wheat, Atlantic states	11.2	1.8	11.7	2.0	71.3	2.0	223
Wheat, Minn., N. D., S. D., Nebr., Kan.	10.4	1.8	13.5	2.4	69.8	2.1	190
Wheat, Miss. Valley, except above states	10.5	1.8	12.3	2.2	71.2	2.0	195
Wheat, Rocky Mountain states	8.5	2.0	13.3	2.1	71.9	2.2	193
Wheat, Pacific states	10.9	1.9	9.9	2.7	72.6	2.0	57
Winter wheat	10.9	1.8	11.7	2.0	71.6	2.0	94
Spring wheat	10.1	2.0	12.5	2.7	70.5	2.2	109
Durum wheat	10.4	1.8	14.1	2.6	68.6	2.5	15
Polish wheat	9.5	2.3	20.3	2.0	64.2	1.7	4
Wheat flour, patent	12.3	0.5	10.9	0.4	74.6	1.3	73
Wheat flour, graham	12.0	1.5	13.7	1.9	68.8	2.1	11
Red dog flour	11.1	2.5	16.8	2.2	63.3	4.1	259
Flour wheat middlings	10.7	3.7	17.8	4.7	58.1	5.0	470
Standard wheat middlings (shorts)	10.5	4.4	17.4	6.0	56.8	4.9	4,641
Wheat bran, all analyses	10.1	6.3	16.0	9.5	53.7	4.4	7,742
Wheat bran, winter	10.6	6.3	15.7	8.8	54.2	4.4	138
Wheat bran, spring	10.4	6.3	15.7	10.2	52.6	4.8	218
Wheat bran, low grade	10.0	6.2	11.9	16.6	51.7	3.6	53
Wheat feed (shorts and bran)	10.1	5.2	16.8	7.6	55.7	4.6	1,601
Wheat screenings	10.2	3.9	13.3	7.4	61.1	4.1	66
Rye and its products							
Rye	9.4	2.0	11.8	1.8	73.2	1.8	108
Rye meal or chop	11.0	1.8	10.9	2.4	71.9	2.0	14
Rye flour	11.8	0.8	7.9	0.4	78.0	1.1	6
Rye middlings	11.4	3.7	15.7	4.6	61.2	3.4	128
Rye bran	11.4	3.5	15.3	4.0	62.7	3.1	26
Rye feed (shorts and bran)	11.5	3.8	15.3	4.7	61.5	3.2	186
Oats and oat products							
Oats	9.2	3.5	12.4	10.9	59.6	4.4	490
Oats, light weight	8.7	4.5	12.3	15.4	54.4	4.7	22
Oat kernel, without hull	6.9	2.2	14.3	1.4	67.1	8.1	179
Oat meal	7.9	2.0	16.0	1.5	66.1	6.5	10
Ground oats, high grade	10.8	3.3	12.1	9.9	59.2	4.7	66
Oat feed, low grade	10.2	4.0	9.6	18.5	53.8	3.9	8
Oat middlings	7.3	3.2	16.3	4.6	61.8	6.8	23
Oat bran	6.4	6.1	12.2	18.3	52.3	4.7	5
Oat dust	6.6	7.0	12.6	18.7	49.9	5.2	5
Oat hulls	6.8	6.0	4.0	29.2	52.3	1.7	16
Corn and oat feed	11.4	2.8	9.6	7.4	65.0	3.8	1,789
Corn and oat feed, low grade	9.5	4.6	8.9	13.7	59.7	3.6	386
Barley, its products, and emmer							
Barley	9.3	2.7	11.5	4.6	69.8	2.1	298
Barley, bald	9.3	2.8	10.8	2.9	71.6	2.6	2
Barley feed	10.2	4.2	12.7	7.8	61.7	3.4	13

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
CONCENTRATES — con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Barley, its products, and emmer—con.							
Barley shorts	10.2	4.2	12.9	10.1	58.7	3.9	7
Barley bran	6.6	5.7	9.1	19.3	56.5	2.8	4
Barley screenings	11.4	4.2	11.5	9.5	60.6	2.8	4
Malt	5.8	2.9	18.0	9.0	60.6	3.7	2
Malt sprouts	7.6	6.1	26.4	12.6	45.6	1.5	253
Brewers' grains, dried	7.5	3.5	26.5	14.6	41.0	6.9	431
Brewers' grains, dried (below 25% protein)	8.2	3.8	23.1	15.0	43.5	6.4	139
Brewers' grains, wet	75.9	1.0	5.7	3.6	12.1	1.7	47
Emmer (spelt)	8.7	3.7	11.9	10.1	63.7	1.9	37
Emmer, without hulls	10.5	1.5	14.9	2.1	68.5	2.5	4
Rice and its products							
Rough rice	9.6	4.9	7.6	9.3	66.7	1.9	10
Polished rice	12.3	0.5	7.4	0.4	79.0	0.4	37
Rice polish	10.0	4.8	11.9	1.9	62.3	9.1	1,013
Rice bran, high grade	10.1	9.7	12.1	12.4	44.3	11.4	831
Rice bran, low grade	9.5	11.3	10.9	15.8	42.7	9.8	475
Rice meal	9.5	9.1	11.8	9.3	48.7	11.6	42
Rice hulls	9.3	16.9	3.3	35.4	34.0	1.1	15
Buckwheat and its products							
Buckwheat	12.1	2.1	10.8	10.3	62.2	2.5	18
Buckwheat flour	12.8	1.1	7.9	0.6	76.1	1.5	11
Buckwheat middlings	12.0	4.8	28.3	4.8	42.7	7.4	54
Buckwheat bran, high grade	11.2	4.2	22.3	7.1	49.4	5.8	12
Buckwheat bran, low grade	10.1	3.1	10.7	33.5	39.9	2.7	16
Buckwheat feed, good grade	11.8	4.4	19.3	17.9	41.4	5.2	18
Buckwheat feed, low grade	11.9	3.2	13.3	28.5	39.7	3.4	29
Buckwheat hulls	10.3	2.1	4.4	43.7	38.5	1.0	15
The sorghums							
Kafir grain	11.8	1.7	11.1	2.3	70.1	3.0	135
Kafir-head chops	12.5	2.8	9.7	6.4	65.9	2.7	21
Milo grain	10.7	2.8	10.7	2.4	70.5	2.9	125
Milo-head chops	10.3	3.1	10.0	5.9	68.1	2.6	40
Feterita grain	10.8	1.5	11.5	1.2	71.7	3.3	1
Durra grain	9.9	2.0	10.1	1.7	72.8	3.5	5
Shallu grain	9.7	1.6	12.5	1.7	71.1	3.4	3
Kaoliang grain	9.9	1.9	10.5	1.5	71.9	4.3	12
Sorghum grain	12.7	1.9	9.2	2.0	70.8	3.4	13
Broom-corn seed	11.8	2.9	10.2	8.2	63.5	3.4	4
Hog, or broom-corn, millet seed	9.1	3.3	11.8	7.8	64.7	3.3	52
Foxtail millet seed	10.8	3.6	12.1	8.4	61.0	4.1	28
Barnyard millet seed	10.2	5.6	10.7	16.0	52.8	4.7	3
Pearl millet seed	8.0	2.3	11.7	2.3	69.0	6.7	1
Cotton seed and its products							
Cotton seed	9.4	4.6	19.5	22.6	24.9	19.0	38
Cottonseed kernel, (without hull)	6.7	5.3	32.8	3.1	17.5	34.6	8
Cottonseed meal, choice	7.5	6.2	44.1	8.1	25.0	9.1	2,556
Cottonseed meal, prime	7.8	6.6	39.8	10.1	27.4	8.3	1,322
Cottonseed meal, good	7.9	6.4	37.6	11.5	28.4	8.2	482
Cold-pressed cottonseed cake	7.9	4.2	26.1	24.0	30.1	7.7	64
Cottonseed feed	8.3	4.9	24.5	21.4	34.6	6.3	406
Cottonseed hulls	9.7	2.7	4.6	43.8	37.3	1.9	66
Cottonseed-hull bran	8.4	2.5	3.4	34.8	49.7	1.2	9

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
CONCENTRATES—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Flax seed and its products							
Flax seed	9.2	4.3	22.6	7.1	23.2	33.7	50
Linseed meal, old process	9.1	5.4	33.9	8.4	35.7	7.5	714
Linseed meal, new process	9.6	5.6	36.9	8.7	36.3	2.9	182
Flax feed	9.4	7.3	16.6	11.2	41.3	14.2	9
Flax screenings	8.6	8.2	15.4	15.5	40.5	11.8	13
Leguminous seeds and their products							
Adzuki bean, *Phaseolus angularis*	14.0	3.6	21.0	4.0	56.7	0.7	2
Bean, navy	13.4	3.6	22.7	5.8	53.0	1.5	4
Bean, navy, cull	12.8	3.3	22.1	3.7	56.7	1.4	3
Cowpea	11.6	3.4	23.6	4.1	55.8	1.5	30
Frijole, *Phaseolus vulgaris*	9.6	4.4	24.6	4.2	56.1	1.1	1
Horse bean	12.6	3.8	26.2	7.1	49.4	0.9	2
Jack bean, *Canavalia ensiformis*	11.5	3.0	23.8	8.7	50.4	2.6	1
Mesquite bean and pod	6.1	4.5	13.0	26.6	46.7	3.1	5
Pea, field	9.2	3.4	22.9	5.6	57.8	1.1	6
Pea, garden	11.8	3.0	25.6	4.4	53.6	1.6	8
Pea meal	10.9	3.6	23.8	4.6	55.7	1.4	8
Pea bran	9.9	5.9	12.2	35.3	35.6	1.1	3
Pea hulls	7.2	3.6	6.9	43.6	37.5	1.2	3
Peanut, with hull	6.5	4.1	20.4	16.4	16.4	36.2	2
Peanut kernel, without hull	6.0	2.2	26.8	2.6	17.5	44.9	11
Peanut waste	4.0	5.4	24.4	6.2	26.6	33.4	3
Peanut cake, from hulled nuts	10.7	4.9	47.6	5.1	23.7	8.0	2,480
Peanut cake, hulls included	5.6	4.5	28.4	23.4	27.0	11.1	7
Peanut hulls	9.1	5.5	7.3	56.6	18.9	2.6	26
Sesbania macrocarpa	9.2	3.3	31.7	13.5	38.0	4.3	1
Soybean	9.9	5.3	36.5	4.3	26.5	17.5	121
Soybean meal, fat extracted	11.8	5.4	41.4	5.3	28.7	7.4	6
Tepary, *Phaseolus acutifolius*, var. *latifolius*	9.5	4.2	22.2	3.4	59.3	1.4	1
Velvet bean, seed	11.7	2.6	20.8	7.5	51.0	6.4	2
Velvet bean, seed and pod	12.3	4.0	17.1	14.3	47.7	4.6	1
Miscel. oil-bearing seeds and their products							
Cocoanut meal, low in fat	9.6	4.9	20.9	11.2	45.3	8.1	11
Cocoanut meal, high in fat	7.7	5.7	20.4	8.0	41.1	17.1	6
Palmnut cake	10.4	4.3	16.8	24.0	35.0	9.5	600
Rapeseed cake	10.0	7.9	31.2	11.3	30.0	9.6	500
Sesame oil cake	9.8	10.7	37.5	6.3	21.7	14.0	150
Sunflower seed, with hulls	6.9	3.1	16.1	27.9	21.3	24.7	9
Sunflower seed, without hulls	4.5	3.8	27.7	6.3	16.3	41.4	6
Sunflower heads	7.3	6.7	12.6	24.4	34.6	14.4	1
Sunflower seed cake	10.0	4.2	34.8	10.9	21.8	18.3	1
Milk and its products							
Cow's milk	86.4	0.7	3.5	...	5.0	4.4	1,647
Cow's milk, colostrum	74.5	1.6	17.6	...	2.7	3.6	42
Skim milk, centrifugal	90.1	0.7	3.8	...	5.2	0.2	...
Skim milk, gravity	90.4	0.7	3.3	...	4.7	0.9	96
Skim milk, dried	8.3	25.1	36.6	...	25.8	4.2	3
Buttermilk	90.6	0.7	3.6	...	5.0	0.1	...
Whey	93.4	0.7	0.8	...	4.8	0.3	...
Mare's milk	90.6	0.4	2.0	...	5.9	1.1	72
Ewe's milk	80.8	0.9	6.5	...	4.9	6.9	...
Sow's milk	81.0	1.0	5.9	...	5.4	6.7	25

Table I. Average percentage composition of American feeding stuffs—*continued*.

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
Concentrates—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Slaughter-house by-products							
Dried blood	9.7	3.3	82.3	...	3.8	0.9	45
Fish meal, high in fat	10.8	29.2	48.4	...	...	11.6	6
Fish meal, low in fat	12.8	32.6	52.4	...	...	2.2	4
Fish-glue waste	14.0	34.9	39.1	...	4.1	7.9	1
Fresh bone	30.4	21.1	19.7	...	3.8	25.0	4
Meat-and-bone meal, 30–40% ash	6.0	36.8	39.8	2.1	4.1	11.2	59
Meat-and-bone meal, over 40% ash	6.6	45.8	33.2	1.6	2.7	10.0	13
Pork cracklings	5.0	2.3	56.4	...	4.1	32.2	5
Poultry bone	7.3	61.7	24.3	...	3.6	3.1	24
Tankage, over 60% protein	7.4	10.5	63.1	3.6	2.5	12.9	42
Tankage, 55–60% protein	7.5	13.6	58.1	4.9	2.9	13.0	57
Tankage, 45–55% protein	7.5	19.7	51.7	3.0	4.2	14.0	53
Tankage, below 45% protein	6.5	22.6	40.4	3.7	9.9	17.0	14
Miscellaneous concentrates							
Acorn, kernel and shell	27.9	1.1	3.4	17.8	45.4	4.4	1
Acorn, kernel	34.4	1.4	4.2	...	54.6	5.4	1
Beet pulp, wet	90.7	0.4	0.9	2.1	5.7	0.2	10
Beet pulp, dried	8.2	3.5	8.9	18.9	59.6	0.9	48
Beet pulp, molasses-	7.6	5.6	9.5	15.9	60.7	0.7	21
Bakery refuse	8.3	5.2	11.2	0.5	65.1	9.7	4
Bread	33.8	1.5	7.9	0.7	55.4	0.7	2
Cassava, dried	5.6	2.0	2.8	5.0	84.1	0.5	6
Cassava starch refuse	12.0	1.6	0.8	6.1	78.8	0.7	1
Chess, or cheat, seed	7.7	4.1	10.5	7.2	68.6	1.9	1
Cocoa shells	4.9	10.3	15.4	16.5	49.9	3.0	21
Corn, oat, and barley feed	9.7	3.5	11.4	9.2	61.7	4.5	60
Distillers' grains, dried, from corn	6.6	2.6	30.7	11.6	36.3	12.2	114
Distillers' grains, dried, from rye	7.2	3.9	23.1	10.9	47.1	7.8	7
Distillers' grains, wet	77.4	0.6	4.5	2.8	13.1	1.6	3
Distillery slop, whole	93.8	0.3	1.9	0.5	2.9	0.6	9
Distillery slop, strained	95.9	0.3	1.4	0.2	1.5	0.7	8
Lamb's-quarter seed, *Chenopodium album*	9.8	3.0	14.1	19.1	46.2	7.8	1
Molasses, beet	25.3	5.2	3.5	...	66.0	...	5
Molasses, cane, or blackstrap	25.8	6.4	3.1	...	64.7	...	16
Molasses feeds, below 10% fiber	11.6	6.7	13.4	9.8	53.5	5.0	171
Molasses feeds, 10–15% fiber	11.7	7.2	12.2	11.8	52.9	4.2	22
Molasses feeds, over 15% fiber	9.3	9.8	13.7	18.6	45.8	2.8	11
Molasses-alfalfa feeds	13.5	9.2	12.0	17.2	46.7	1.4	5
Molassine meal	16.6	7.8	8.8	6.4	59.6	0.8	3
Mustard feed or bran	5.7	6.2	31.7	10.7	34.1	11.6	3
Pigeon-grass seed	10.7	6.6	14.4	17.2	45.7	5.4	3
Pigweed seed	6.3	4.2	15.0	15.2	52.5	6.8	1
Potato flakes, dried	12.1	4.0	7.1	2.9	73.6	0.3	...
Potato flour	10.6	2.4	2.7	2.2	81.3	0.8	2
Starch feed, dry	9.3	1.8	15.4	7.2	59.4	6.9	13
Starch feed, wet	66.6	0.3	5.6	3.1	21.1	3.3	19
Starch refuse	10.3	1.6	6.3	7.3	73.1	1.4	3
Dried Roughage							
Cured corn and sorghum forage, etc.							
Corn fodder (ears, if any, remaining), very dry, from barn or in arid districts	9.0	6.5	7.8	27.2	47.3	2.2	56
Corn fodder, medium in water	18.3	5.0	6.7	22.0	45.8	2.2	59
Corn fodder, high in water	39.3	3.6	4.8	16.7	34.2	1.4	23

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
DRIED ROUGHAGE—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Cured corn and sorghum forage, etc.— con.							
Sweet corn fodder	12.3	9.0	9.2	26.4	41.3	1.8	6
Corn stover (ears removed), very dry	9.4	5.8	5.9	30.7	46.6	1.6	183
Corn stover, medium in water	19.0	5.5	5.7	27.7	40.9	1.2	97
Corn stover, high in water	41.0	3.8	3.9	20.1	30.2	1.0	247
Corn leaves	23.4	6.2	7.1	22.1	39.4	1.8	28
Corn husks	24.7	2.5	2.9	24.9	44.2	0.8	17
Corn stalks	17.7	5.2	4.8	27.8	43.1	1.4	19
Corn tops	17.9	5.6	5.6	27.4	42.0	1.5	8
New corn product	9.2	4.0	6.4	28.7	48.9	2.8	1
Kafir fodder, dry	9.0	9.4	8.9	26.8	43.1	2.8	20
Kafir fodder, high in water	28.3	3.3	6.5	21.6	37.6	2.7	2
Kafir stover, dry	16.3	8.3	5.1	27.4	41.2	1.7	3
Kafir stover, high in water	27.3	7.3	3.8	23.7	36.6	1.3	4
Milo fodder, dry	11.1	9.9	12.0	18.4	44.1	4.5	5
Milo fodder, high in water	39.1	3.1	3.7	17.5	34.3	2.3	7
Milo stover, high in water	35.5	6.7	2.3	20.6	34.1	0.8	1
Sorghum fodder, dry	9.7	7.8	7.4	26.1	45.9	3.1	22
Sorghum fodder, high in water	37.4	3.1	3.9	17.8	35.0	2.8	11
Sorghum bagasse, dried	11.3	2.9	3.4	30.5	50.5	1.4	2
Durra fodder	10.1	5.2	6.4	24.1	51.4	2.8	3
Broom-corn fodder	9.4	5.7	3.9	36.8	42.4	1.8	1
Japanese cane fodder	6.8	2.0	1.4	20.6	67.3	1.9	1
Sugar-cane bagasse	10.2	5.6	3.3	34.6	39.2	7.1	1
Hay from the grasses, etc.							
Bent grass, Canada, or blue joint, *Calamagrostis Canadensis*	6.7	6.8	7.6	34.7	41.8	2.4	10
Bermuda grass	9.7	7.6	7.1	25.6	48.2	1.8	14
Black grass, *Juncus Gerardi*	10.3	7.3	7.5	25.1	47.3	2.5	21
Bluegrass, Canada	10.7	5.8	6.6	28.2	46.4	2.3	10
Bluegrass, Kentucky, all analyses	13.2	6.6	8.3	28.3	40.7	2.9	26
Bluegrass, Kentucky, in milk	12.4	5.9	8.5	23.4	47.0	2.8	2
Bluegrass, Kentucky, ripe	23.7	6.5	6.1	25.4	35.3	3.0	5
Bluegrasses, native western	8.1	8.0	11.2	29.8	39.9	3.0	7
Brome grass, smooth	8.5	7.7	9.9	31.3	40.2	2.4	8
Bluestem grasses, *Andropogon* spp.	6.9	5.5	4.9	34.2	46.7	1.8	10
Buffalo grass, *Bulbilis dactyloides*	7.0	11.5	7.0	26.1	46.6	1.8	7
Bunch grasses, miscellaneous	7.0	9.2	6.0	30.6	45.4	1.8	9
Carpet grass	7.9	10.2	7.0	31.8	40.9	2.2	1
Chess, or cheat, *Bromus secalinus*	8.4	7.9	7.2	28.0	46.2	2.3	10
Crab grass	9.5	8.5	8.0	28.7	42.9	2.4	9
Crow-foot grass, *Eleusine* spp.	9.5	7.9	8.6	27.4	44.4	2.2	10
Fescue, meadow	11.7	7.0	6.8	30.4	42.1	2.0	21
Fescues, native, *Festuca* spp.	4.9	5.8	8.9	33.5	44.8	2.1	9
Fowl meadow grass	11.1	7.2	9.8	28.8	40.4	2.7	5
Foxtails, miscellaneous	6.8	10.1	9.3	28.6	42.6	2.6	14
Gama grass, *Tripsacum dactyloides*	11.8	6.2	6.7	30.4	43.1	1.8	3
Grama grasses, *Bouteloua* spp.	6.6	9.0	6.4	28.7	47.6	1.7	15
Hair grasses, miscellaneous	6.6	6.8	8.3	31.2	44.9	2.2	17
Johnson grass	10.1	7.5	6.6	30.2	43.5	2.1	17
Millet, barnyard	13.5	8.2	8.3	27.6	40.8	1.6	14
Millet, common, or Hungarian	14.3	6.3	8.3	24.0	44.3	2.8	56
Millet, German	8.7	6.9	8.0	27.3	46.5	2.6	22

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
DRIED ROUGHAGE—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Hay from the grasses, etc.—con.							
Millet, hog, or broom-corn	9.3	5.9	8.8	21.3	52.2	2.5	5
Millet, pearl, or cat-tail	12.8	9.0	6.7	33.0	36.8	1.7	6
Millet, wild, or Indian	6.7	6.9	10.6	30.7	42.7	2.4	7
Mixed grasses	12.8	5.6	7.6	28.8	42.7	2.5	359
Mixed grasses, rowen	13.6	6.5	12.3	24.2	40.1	3.3	49
Natal grass, *Tricholaena rosea*	9.8	5.0	7.4	36.8	39.2	1.8	....
Needle grasses, *Stipa* spp.	5.3	5.5	7.8	34.0	45.6	1.8	9
Nerved manna grass, *Panicularia nervata*	6.2	8.5	8.0	28.6	46.8	1.9	4
Oat grass, tall, or meadow oat grass, *Arrhenatherum elatius*	11.8	6.1	8.0	29.4	42.1	2.6	13
Old witch grass, *Panicum capillare*	7.1	10.1	10.6	24.3	45.7	2.2	3
Orchard grass	11.6	6.9	7.9	30.3	40.4	2.9	46
Para grass	9.8	6.6	4.6	33.6	44.5	0.9	3
Panic grasses, *Panicum* spp	7.9	7.1	8.3	29.5	44.9	2.3	21
Prairie hay, western	6.5	7.7	8.0	30.5	44.7	2.6	42
Quack, or couch grass, *Agropyron repens*	5.9	7.3	7.3	36.5	41.0	2.0	4
Rescue grass	9.8	8.1	9.8	24.6	44.5	3.2	3
Red top, all analyses	9.8	6.8	7.4	28.7	45.0	2.3	40
Red top, in bloom	8.0	8.1	7.2	29.9	44.7	2.1	15
Reed bent grass, *Calamagrostis purpurascens*	5.9	5.1	10.2	31.2	45.3	2.3	3
Reed canary grass, *Phalaris arundinacea*	9.6	7.9	7.9	29.0	42.9	2.7	10
Reed grasses, miscellaneous western	7.0	7.0	6.2	33.3	44.3	2.2	8
Reed meadow grass, or manna, *Panicularia Americana*	6.7	9.7	9.3	29.5	42.9	1.9	7
Rhode Island bent, *Agrostis canina*	11.5	6.6	6.6	29.5	42.8	3.0	2
Rye grass, Italian	11.4	7.5	8.1	27.8	43.3	1.9	7
Rye grass, perennial	12.0	8.1	9.2	24.2	43.4	3.1	14
Rushes, western, *Juncus* spp.	5.7	7.6	10.2	29.2	45.5	1.8	28
Salt grasses, miscellaneous	5.3	12.6	8.1	30.5	41.5	2.0	4
Sedges, western, *Carex* spp	5.2	6.8	11.2	28.2	46.3	2.3	45
Sedges, eastern, *Carex* spp	9.3	7.4	6.1	29.2	46.3	1.7	3
Spear grasses, *Poa* spp	5.5	5.8	7.6	30.0	49.0	2.1	33
Swamp grasses	9.8	7.7	7.7	28.2	44.3	2.3	37
Sweet vernal grass, *Anthoxanthum oderatum*	9.3	9.3	12.4	21.7	42.7	4.6	2
Teosinte	10.6	10.3	9.1	26.4	41.7	1.9	4
Timothy, all analyses	11.6	4.9	6.2	29.9	45.0	2.5	221
Timothy, before bloom	7.2	6.6	9.8	28.1	45.1	3.2	7
Timothy, early to full bloom	12.8	4.6	6.3	29.5	44.2	2.6	50
Timothy, late bloom to early seed	14.9	4.5	5.5	28.3	44.0	2.8	21
Timothy, nearly ripe	12.5	4.3	5.2	30.7	45.1	2.2	28
Timothy, rowen	15.1	6.9	14.4	24.3	34.9	4.4	3
Wheat grass, common, *Agropyron glaucum*	7.3	6.9	6.5	27.4	49.4	2.5	4
Wheat grasses, miscellaneous, *Agropyron* spp.	6.4	6.2	7.1	30.2	47.7	2.4	19
Wheat grass, western, *Agropyron occidentale*	5.9	7.0	7.7	32.7	44.4	2.3	13
Wild barley, or foxtail, *Hordeum jubatum*	7.5	8.8	7.0	27.4	47.3	2.0	5
Wild oat, *Avena fatua*	7.9	6.4	8.0	30.1	44.8	2.8	13
Wild rye, *Elymus Canadensis*	10.8	7.3	7.1	26.1	46.8	1.9	10

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
DRIED ROUGHAGE—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Hay from the smaller cereals							
Barley hay, common	7.4	6.4	7.0	29.7	47.3	2.2	5
Barley hay, bald	8.7	6.9	7.4	21.9	53.0	2.1	5
Emmer hay	7.7	9.3	10.0	33.6	37.3	2.1	4
Oat hay	12.0	6.8	8.4	28.3	41.7	2.8	72
Rye hay, all analyses	8.1	5.1	6.7	37.5	40.5	2.1	12
Rye hay, heading out to in bloom	8.2	5.8	9.8	33.9	39.7	2.6	3
Wheat hay	8.1	6.4	6.2	24.7	52.6	2.0	12
Hay from the legumes							
Alfalfa, all analyses	8.6	8.6	14.9	28.3	37.3	2.3	250
Alfalfa, first cutting	8.5	8.8	13.9	30.9	36.2	1.7	46
Alfalfa, second cutting	7.3	9.0	14.7	31.9	35.4	1.7	33
Alfalfa, third cutting	8.9	9.5	14.6	28.4	36.8	1.8	17
Alfalfa, fourth cutting	16.0	7.8	15.9	24.6	34.0	1.7	3
Alfalfa, before bloom	6.2	10.0	22.0	20.5	37.1	4.2	11
Alfalfa, in bloom	7.5	10.0	15.0	30.2	35.5	1.8	31
Alfalfa, in seed	10.4	7.0	12.2	27.6	40.3	2.5	10
Alfalfa, variegated, or sand lucerne	15.2	8.3	14.2	27.8	32.3	2.2	4
Alfalfa meal	8.8	9.0	14.3	30.1	35.8	2.0	176
Alfalfa leaves	6.6	13.6	22.5	12.7	41.2	3.4	6
Alfalfa stems	5.6	4.9	6.3	54.4	27.9	0.9	2
Bean, whole plant	12.6	3.5	22.5	4.4	55.2	1.8	....
Beggarweed	9.1	8.4	15.4	27.5	37.3	2.3	11
Clover, alsike, all analyses	12.3	8.3	12.8	25.7	38.4	2.5	32
Clover, alsike, in bloom	12.6	7.7	13.2	26.4	37.0	3.1	5
Clover, bur	7.0	10.8	19.2	23.0	37.0	3.0	11
Clover, crimson, or scarlet	10.6	8.8	14.1	27.3	36.9	2.3	18
Clover, Egyptian, or berseem, *Trifolium Alexandrinum*	7.5	9.5	14.4	23.2	43.0	2.4	2
Clover, mammoth red	18.7	6.2	10.8	27.0	34.2	3.1	19
Clover, red, all analyses	12.9	7.1	12.8	25.5	38.7	3.1	76
Clover, red, before bloom	10.4	7.2	18.7	18.3	41.8	3.6	2
Clover, red, in bloom	13.9	7.4	13.1	23.1	39.1	3.4	18
Clover, red, after bloom	22.1	6.0	11.6	21.9	33.8	4.6	5
Clover, sweet, white	8.6	7.2	14.5	27.4	40.1	2.2	18
Clover, sweet, yellow	8.7	6.0	13.4	38.8	31.5	1.6	1
Clover, white	8.1	8.0	16.2	23.2	41.6	2.9	7
Clover meal	8.5	7.2	13.7	25.9	42.4	2.3	12
Clover rowen	14.8	7.3	16.5	20.4	37.3	3.7	2
Cowpea, all analyses	9.7	11.9	19.3	22.5	34.0	2.6	35
Cowpea, before bloom	7.8	17.3	26.2	20.6	25.5	2.6	13
Cowpea, in bloom to early pod	10.6	10.2	18.5	21.0	36.4	3.3	6
Cowpea, ripe	10.0	6.4	10.1	29.2	41.8	2.5	3
Flat pea, *Lathyrus silvestris*, var. *Wagneri*	7.7	6.7	22.7	27.7	32.0	3.2	5
Kudzu vine	7.1	6.8	16.7	25.0	41.2	3.2	1
Lespedeza, or Japan clover	11.8	5.8	12.1	25.9	41.6	2.8	14
Lupines, *Lupinus* spp.	7.8	8.8	15.8	20.8	43.5	3.3	13
Pea, field	11.1	7.9	15.1	24.5	37.9	3.5	30
Pea, field, without peas	9.4	6.6	9.5	27.7	45.2	1.6	3
Peanut vine, with nuts	7.8	6.8	13.3	24.3	37.4	10.4	3
Peanut vine, without nuts	21.5	8.7	9.1	20.2	36.8	3.7	7
Sanfoin, *Onobrychis viciaefolia*	15.9	7.1	10.5	19.7	44.2	2.6	5
Serradella	9.7	12.3	15.7	19.6	40.2	2.5	5
Soybean hay	8.6	8.6	16.0	24.9	39.1	2.8	23

TABLE I. Average percentage composition of American feeding stuffs—*continued*.

Feeding stuff	Water	Ash	Crude protein	Carbohydrates: Fiber	Carbohydrates: N-free extract	Fat	No. of analyses
DRIED ROUGHAGE—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Hay from the legumes—con.							
Trefoil, yellow, or black medic, *Medicago lupulina*	11.2	10.9	16.9	14.8	43.2	3.0	2
Velvet bean	7.2	7.4	16.4	27.5	38.4	3.1	4
Vetch, common	7.1	8.2	17.3	26.2	38.7	2.5	3
Vetch, hairy	12.3	8.6	19.9	24.8	31.6	2.8	15
Vetch, kidney, *Anthyllis vulneraria*	9.7	11.2	12.1	26.5	38.9	1.6	4
Vetches, wild	6.6	8.2	17.0	26.0	39.8	2.4	12
Hay from mixed legumes and grasses							
Clover and mixed grasses	10.1	6.4	9.9	28.5	42.3	2.8	34
Clover and timothy	12.2	6.1	8.6	29.9	40.8	2.4	52
Clover mixed rowen	13.0	5.8	11.8	27.9	38.6	2.9	11
Cowpeas and millet	9.7	14.8	13.7	27.6	32.0	2.2	2
Peas and oats	16.6	7.3	11.4	25.6	36.5	2.6	30
Peas, oats, and barley	16.5	6.0	12.6	29.5	32.4	3.0	1
Vetch and oats	15.7	6.7	10.6	27.2	37.3	2.5	8
Vetch and wheat	15.0	6.8	14.5	27.2	34.4	2.1	4
Straw and chaff from the cereals							
Barley straw	14.2	5.7	3.5	36.0	39.1	1.5	97
Buckwheat straw	9.9	5.5	5.2	43.0	35.1	1.3	3
Flax shives	7.2	7.0	7.2	42.5	32.9	3.2	11
Millet straw	14.2	5.2	3.6	35.8	39.7	1.5	6
Oat straw	11.5	5.4	3.6	36.3	40.8	2.4	41
Oat chaff	8.2	11.5	5.9	25.7	46.3	2.4	4
Rice straw	7.5	14.5	3.9	33.5	39.2	1.4	13
Rye straw	7.1	3.2	3.0	38.9	46.6	1.2	7
Wheat straw	8.4	5.2	3.1	37.4	44.4	1.5	27
Wheat straw from rusted grain	8.1	6.4	8.7	40.9	34.6	1.3	8
Wheat chaff	14.4	7.2	4.2	28.0	44.8	1.4	1
Legume straws							
Bean	10.5	7.2	7.3	30.8	42.9	1.3	5
Crimson clover	12.3	7.0	7.5	38.8	32.9	1.5	3
Cowpea	8.5	5.4	6.8	44.5	33.6	1.2	1
Horse bean	12.1	8.4	8.6	36.4	33.1	1.4	2
Soybean	11.9	6.8	5.6	36.8	37.2	1.7	8
Miscellaneous dry roughages							
Alfilaria, *Erodium cicutarium*	11.1	11.4	11.1	23.0	40.2	3.2	3
Artichoke tops	25.8	7.0	4.2	22.0	40.1	0.9	1
Brush feed	5.0	2.8	5.4	46.5	37.9	2.4	1
Burnet, *Sanguisorba minor*	11.1	8.8	13.0	20.7	42.5	3.9	5
Daisy, field	9.3	10.2	14.1	22.0	40.1	4.3	4
Furze	5.5	7.0	11.6	38.5	35.4	2.0	1
Greasewood	4.6	14.4	19.8	24.5	34.3	2.4	1
Lamb's quarter	9.7	16.5	24.0	12.3	33.2	4.3	1
Prickly comfrey	7.9	22.0	25.5	8.7	32.8	3.1	1
Purslane	11.9	22.9	22.3	14.2	24.5	4.2	1
Rape	11.3	14.5	18.9	12.8	39.2	3.3	5
Russian thistle	5.8	15.9	18.2	25.0	32.1	3.0	1
Saltbushes, *Atriplex* spp	6.6	17.4	13.5	22.6	38.4	1.5	25
Spurrey, *Spergula arvensis*	7.9	10.4	11.3	19.1	46.8	4.5	7
Sweet potato vines	11.3	9.2	12.5	20.2	43.5	3.3	6

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates: Fiber	Carbohydrates: N-free extract	Fat	No. of analyses
FRESH GREEN ROUGHAGE	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Corn and the sorghums							
Corn fodder, all analyses	78.1	1.2	1.9	5.2	13.0	0.6	708
Dent corn fodder, all analyses	76.9	1.2	1.9	5.5	13.9	0.6	260
Dent corn fodder, in tassel	85.1	1.1	1.6	4.3	7.6	0.3	9
Dent corn fodder, in milk	80.1	1.1	1.6	4.9	11.7	0.6	16
Dent corn fodder, dough to glazing	74.9	1.1	2.1	5.6	15.4	0.9	15
Dent corn fodder, kernels glazed	73.8	1.2	2.0	6.2	16.2	0.6	26
Dent corn fodder, kernels ripe	65.2	1.4	2.7	7.4	22.3	1.0	7
Flint corn fodder, all analyses	79.3	1.0	1.9	4.6	12.6	0.6	94
Flint corn fodder, in tassel	89.4	0.8	1.4	3.2	4.8	0.4	4
Flint corn fodder, in milk	85.0	0.8	1.5	3.6	8.6	0.5	3
Flint corn fodder, kernels glazed	79.0	1.1	1.9	4.2	12.9	0.9	15
Flint corn fodder, kernels ripe	72.1	1.3	2.4	6.1	17.0	1.1	1
Sweet corn fodder, before milk stage	90.0	1.0	1.0	2.5	5.2	0.3	5
Sweet corn fodder, roasting ears or later	79.7	1.2	1.9	4.4	12.2	0.6	55
Sweet corn fodder, ears removed	78.5	1.3	1.6	5.6	12.6	0.4	3
Sweet corn ears, including husks	62.2	0.9	3.8	4.3	26.2	2.6	3
Corn fodder, pop	83.1	1.0	1.3	6.0	8.2	0.4	2
Corn stover, green (ears removed)	77.3	1.4	1.3	6.0	13.6	0.4	18
Corn leaves and tops	84.1	1.2	1.9	4.4	7.8	0.6	2
Corn leaves	68.9	3.2	3.2	8.6	15.4	0.7	22
Corn husks	63.5	1.5	1.8	11.9	20.9	0.4	22
Corn stalks, stripped	73.6	1.1	1.3	9.1	14.5	0.4	42
Kafir fodder, all analyses	76.4	1.9	2.4	6.6	12.0	0.7	56
Kafir fodder, heads just showing	80.1	1.3	1.6	6.5	10.1	0.4	5
Milo fodder	77.3	1.4	1.8	7.0	12.1	0.4	9
Sweet sorghum fodder	75.1	1.4	1.5	7.0	14.0	1.0	94
Durra fodder	77.6	1.8	2.0	6.2	11.8	0.6	3
Broom-corn fodder	77.1	1.7	2.0	8.6	10.1	0.5	1
Sugar cane	78.3	1.4	0.9	6.2	12.2	1.0	8
Fresh green grass							
Bent grass, Canada, or bluejoint, *Calamagrostis Canadensis*	55.4	4.1	4.1	15.2	20.0	1.2	3
Bermuda grass	66.8	2.3	3.0	8.0	18.9	1.0	2
Bluegrass, Canada	66.8	2.6	3.0	10.3	16.1	1.2	9
Bluegrass, Kentucky, all analyses	68.4	2.8	4.1	8.7	14.8	1.2	32
Bluegrass, Kentucky, before heading	76.2	2.7	5.3	5.2	9.3	1.3	7
Bluegrass, Kentucky, headed out	63.6	3.7	4.9	10.9	15.6	1.3	4
Bluegrass, Kentucky, after bloom	56.4	4.1	3.4	13.2	21.6	1.3	2
Bluegrasses, native	54.7	2.5	3.2	15.0	23.3	1.3	5
Brome grass, smooth	67.0	2.9	4.2	9.3	15.1	1.5	35
Brome grasses, miscellaneous	63.7	3.2	4.5	11.9	15.7	1.0	17
Bluejoint grasses, western, *Andropogon* spp	61.1	2.8	2.6	12.8	19.8	0.9	5
Bluestem grasses, *Andropogon* spp	68.4	2.4	3.0	10.5	14.2	1.5	16
Bunch grasses, miscellaneous	50.6	4.2	4.3	15.8	23.9	1.2	1
Chess, or cheat, *Bromus secalinus*	60.4	1.8	3.2	13.0	20.5	1.1	1
Crab grass	69.1	4.3	2.7	9.1	13.8	1.0	6
Fescue, meadow	69.5	2.4	3.0	10.1	14.0	1.0	33
Fescues, native, *Festuca* spp	64.0	2.5	3.5	12.5	16.7	0.8	10
Guinea grass, *Panicum maximum*	71.5	2.6	2.2	10.9	12.1	0.7	1
Grama grass, *Bouteloua* spp	63.9	2.5	3.3	12.7	16.7	0.9	3
Johnson grass	70.9	2.0	2.5	9.3	14.4	0.9	14
Meadow foxtail	70.4	2.7	3.6	8.0	14.1	1.2	4

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
FRESH GREEN ROUGHAGE—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Fresh green grass — con.							
Millet, barnyard	78.7	1.6	1.7	6.7	10.7	0.6	43
Millet, common, or Hungarian	72.4	2.1	2.9	8.4	13.3	0.9	19
Millet, hog, or broom-corn	75.3	1.8	2.0	7.4	12.9	0.6	11
Millet, pearl, or cat-tail	81.3	1.6	1.8	6.2	8.8	0.3	5
Mixed grasses, immature	70.3	3.0	5.1	6.3	13.8	1.5	6
Mixed grasses, at haying stage	69.2	1.8	3.0	10.6	14.1	1.3	7
Oat grass, tall, or meadow oat grass, *Arrhenatherum elatius*	69.7	2.0	2.6	10.5	14.3	0.9	31
Orchard grass	70.8	2.5	2.9	9.8	12.9	1.1	57
Para grass	72.8	2.4	1.7	9.2	13.4	0.5	2
Quack grass, *Agropyron repens*	75.0	2.5	3.8	7.0	10.5	1.2	6
Rescue grass	69.4	2.4	3.8	8.6	14.8	1.0	8
Red top	60.7	2.7	3.1	12.2	20.2	1.1	16
Reed canary grass, *Phalaris arundinacea*	63.0	2.9	3.6	10.9	18.5	1.1	5
Reed meadow grass, or manna, *Panicularia Americana*	69.3	2.5	2.8	10.0	14.8	0.6	3
Rhode Island bent grass, *Agrostis canina*	67.3	2.6	2.9	10.6	15.9	0.7	3
Rowen, mixed	71.8	2.4	4.7	7.3	12.3	1.5	6
Rye grass, Italian	72.9	2.5	3.1	6.8	13.4	1.3	25
Rye grass, perennial	73.4	2.4	3.0	6.7	13.2	1.3	25
Rushes, western, *Juncus* spp	68.9	2.2	3.4	9.8	15.1	0.6	11
Sedges, western, *Carex* spp	61.5	3.2	3.8	11.4	19.0	1.1	15
Spear grasses, miscellaneous	56.4	2.7	3.3	14.7	21.9	1.0	13
Sweet vernal grass, *Anthoxanthum oderatum*	68.8	2.0	2.6	9.7	15.9	1.0	6
Teosinte	78.7	2.0	1.7	6.7	10.4	0.5	19
Timothy, all analyses	62.5	2.2	3.1	11.7	19.3	1.2	88
Timothy, before bloom	75.8	1.7	2.5	7.3	12.0	0.7	5
Timothy, in bloom	67.9	2.0	2.7	10.4	16.1	0.9	15
Timothy, in seed	53.6	2.3	3.1	15.3	24.4	1.3	13
Timothy, mountain, *Phleum alpinum*	62.5	1.8	3.0	12.9	18.8	1.0	3
Wheat grasses, miscellaneous, *Agropyron* spp	54.7	3.2	4.0	15.7	21.1	1.3	15
Wild barley, or foxtail, *Hordeum jubatum*	64.3	3.5	4.9	11.8	14.1	1.4	9
Wild oats, *Avena fatua*	63.4	2.7	2.6	8.6	21.3	1.4	5
Wild rye, *Elymus Canadensis*	76.7	2.2	3.7	7.5	8.9	1.0	5
Green fodder from the smaller cereals							
Barley fodder	76.8	2.1	3.3	6.0	11.0	0.8	15
Buckwheat, Japanese	63.4	3.6	4.6	8.0	19.5	0.9	1
Oat fodder	73.9	2.1	3.2	7.8	11.9	1.1	22
Oat fodder, 8 in. high	87.0	1.6	4.9	1.7	4.0	0.8	1
Rye fodder	78.7	1.7	2.6	7.3	9.0	0.7	38
Rye fodder, 5 in. high	81.9	2.2	6.5	2.0	6.5	0.9	1
Wheat fodder, all analyses	72.6	2.7	3.6	7.5	12.8	0.8	15
Wheat fodder, 5 in. high	75.8	3.0	6.5	3.9	10.1	0.7	1
Green legumes							
Alfalfa, all analyses	74.7	2.4	4.5	7.0	10.4	1.0	143
Alfalfa, before bloom	80.1	2.3	4.7	4.2	7.9	0.8	11
Alfalfa, in bloom	74.1	2.5	4.4	7.8	10.4	0.8	27
Alfalfa, after bloom	70.2	2.2	2.9	12.8	11.3	0.6	6
Beggarweed	72.9	3.2	4.2	7.5	11.7	0.5	3
Clover, alsike	75.7	2.4	4.1	6.5	10.7	0.6	17
Clover, alsike, in bloom	78.5	2.2	3.5	5.9	9.3	0.6	12

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
FRESH GREEN ROUGHAGE—con.							
Green legumes — con.							
Clover, bur	79.2	2.3	5.1	3.9	7.8	1.7	3
Clover, crimson	82.6	1.7	3.0	4.7	7.4	0.6	22
Clover, mammoth red	74.9	2.3	4.0	7.3	11.0	0.5	7
Clover, red, all analyses	73.8	2.1	4.1	7.3	11.7	1.0	85
Clover, red, in bloom	72.5	2.0	4.1	8.2	12.1	1.1	36
Clover, red, rowen	65.6	2.5	5.3	9.1	16.2	1.3	7
Clover, sweet	75.6	2.1	4.4	7.0	10.2	0.7	18
Clover, white	78.2	2.7	4.6	4.2	9.5	0.8	6
Cowpeas	83.7	2.0	3.0	3.8	7.0	0.5	144
Flat pea, *Lathyrus silvestris*, var.	77.5	1.6	5.7	6.4	8.0	0.8	8
Jack bean, *Canavalia ensiformis*	76.8	2.7	5.2	6.4	8.4	0.5	1
Horse bean	82.4	2.0	3.6	4.2	7.3	0.5	5
Lupines	82.6	1.6	3.4	4.6	7.2	0.6	9
Peas, field, Canada	83.4	1.6	3.6	4.0	6.9	0.5	33
Peas, field, miscellaneous	81.2	1.6	3.2	5.3	8.1	0.6	16
Kudzu vine	69.4	2.2	5.5	8.3	13.6	1.0	1
Lespedeza, or Japan clover	63.4	3.5	6.7	10.7	14.7	1.0	1
Sanfoin, *Onobrychis viciaefolia*	74.4	2.4	3.8	6.2	12.4	0.8	4
Serradella	79.8	3.0	2.9	4.8	8.8	0.7	8
Soybeans, all analyses	76.4	2.4	4.1	6.3	9.8	1.0	145
Soybeans, in bloom	79.2	2.3	3.9	5.8	8.2	0.6	8
Soybeans, in seed	75.8	2.4	4.0	6.4	10.4	1.0	21
Trefoil, yellow, or black medic, *Medicago lupulina*	77.3	2.3	4.5	5.6	9.5	0.8	2
Velvet bean	82.1	2.0	3.5	5.1	6.6	0.7	1
Vetch, common	79.6	2.1	3.8	5.5	8.5	0.5	14
Vetch, kidney, *Anthyllis vulneraria*	72.3	3.2	3.7	8.3	12.0	0.5	5
Vetch, hairy	81.8	2.2	4.2	5.0	6.3	0.5	21
Vetches, wild	75.4	2.1	5.1	6.9	10.0	0.5	6
Mixed legumes and grasses							
Clover and mixed grasses	72.7	1.6	3.0	8.5	13.3	0.9	19
Cowpeas and corn	80.0	1.8	2.1	5.3	10.4	0.4	1
Cowpeas and oats	78.2	2.2	4.5	5.7	8.5	0.9	3
Cowpeas and sorghum	81.3	1.7	1.5	5.5	9.5	0.5	2
Peas and millet	80.3	2.6	2.6	6.6	6.6	1.3	3
Peas and barley	79.8	1.7	3.6	5.2	8.9	0.8	11
Peas and oats	77.4	2.0	3.2	6.3	10.1	1.0	46
Peas, oats, and rape	82.1	2.7	3.1	4.3	7.0	0.8	3
Soybeans and corn	76.2	1.7	2.7	5.4	13.2	0.8	9
Soybeans and kafir	82.9	2.1	2.0	6.2	6.2	0.6	1
Vetch and barley	80.0	1.2	2.8	6.5	9.0	0.5	2
Vetch and oats	73.5	2.3	3.8	7.5	12.0	0.9	15
Vetch and wheat	77.3	1.6	3.3	7.1	10.1	0.6	5
Roots, tubers, etc.							
Artichoke	79.5	1.7	2.0	0.8	15.9	0.1	22
Beet, common	87.0	1.5	1.6	0.9	8.9	0.1	23
Beet, sugar	83.6	1.1	1.6	1.0	12.6	0.1	86
Carrot	88.3	1.2	1.2	1.1	8.0	0.2	18
Cassava	67.4	1.0	1.1	1.4	28.8	0.3	3
Chufa	79.5	0.4	0.7	2.2	10.5	6.6	....
Mangel	90.6	1.0	1.4	0.8	6.1	0.1	38
Onion	87.6	0.5	1.3	0.7	9.6	0.3	6

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
FRESH GREEN ROUGHAGE—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Roots, tubers, etc.—con.							
Parsnip	83.4	1.3	1.7	1.3	11.9	0.4	2
Potato	78.8	1.1	2.2	0.4	17.4	0.1	465
Rutabaga	89.1	1.0	1.2	1.4	7.0	0.3	10
Sweet potato	68.8	1.1	1.8	1.3	26.4	0.6	145
Turnip	90.5	0.9	1.4	1.1	5.9	0.2	20
Miscellaneous green forages							
Alfilaria, *Erodium cicutarium*	83.7	3.0	3.2	2.9	6.8	0.4	2
Apple	81.8	0.4	0.5	1.3	15.6	0.4	9
Apple pomace	76.7	1.0	1.6	4.6	14.5	1.6	17
Burnet	80.1	2.0	3.0	4.6	9.6	0.7	3
Cabbage	91.1	0.8	2.2	0.9	4.7	0.3	5
Cabbage waste, outer leaves	85.9	3.1	2.7	2.8	5.1	0.4	2
Cactus, cane, entire plant	89.6	1.7	0.9	1.1	6.5	0.2	5
Cactus, cane, fruit	81.4	2.7	1.5	3.2	10.4	0.8	35
Cactus, cane, stems	78.3	3.8	1.5	3.4	12.6	0.4	42
Cactus, prickly pear	83.5	3.4	0.8	2.3	9.7	0.3	94
Cactus, prickly pear, old joints	83.6	3.2	0.6	2.5	9.8	0.3	4
Cactus, prickly pear, young joints	87.1	2.6	0.9	1.2	7.8	0.4	5
Kale	88.7	1.9	2.4	1.5	5.0	0.5	12
Kohlrabi	91.0	1.3	2.0	1.3	4.3	0.1	2
Melon, pie, or stock	93.9	0.4	0.7	1.4	3.4	0.2	3
Mustard, white, *Brassica alba*	86.0	2.1	4.1	1.7	5.5	0.6	2
Potato pomace, wet	91.7	0.3	0.7	0.9	6.3	0.1	2
Prickly comfrey	87.2	2.3	2.5	1.8	5.9	0.3	20
Pumpkin, field	91.7	0.9	1.4	1.3	4.2	0.5	4
Purslane	89.7	1.9	2.2	1.5	4.4	0.3	3
Rape	83.3	2.2	2.9	2.6	8.4	0.6	37
Russian thistle	79.6	3.8	3.0	4.8	8.3	0.5	5
Saltbush, Australian	76.7	5.4	3.7	4.4	9.4	0.4	7
Saltbushes, miscellaneous	75.7	5.1	3.9	4.2	10.8	0.3	3
Sugar beet leaves	88.4	1.8	1.9	1.1	6.5	0.3	5
Sugar beet tops	88.6	2.0	2.6	1.2	5.3	0.3	4
Sunflower, whole plant	76.3	2.6	3.6	4.0	11.4	2.1	3
Turnip tops	85.0	3.0	2.8	1.5	7.3	0.4	5
SILAGE							
Silage from corn, the sorghums, etc.							
Corn, well matured, recent analyses	73.7	1.7	2.1	6.3	15.4	0.8	121
Corn, immature	79.0	1.4	1.9	5.8	11.3	0.6	53
Corn, early analyses	76.9	1.4	1.9	6.2	12.7	0.9	372
Corn, from frosted corn	74.7	1.8	2.2	6.1	14.4	0.8	10
Corn, from field-cured stover	80.4	1.4	1.4	6.3	9.8	0.7	3
Durra	79.7	1.9	1.2	7.0	9.5	0.7	3
Kafir	69.2	2.5	1.8	9.9	15.5	1.1	3
Sorghum, sweet	77.2	1.6	1.5	6.9	11.9	0.9	30
Japanese cane	77.6	2.0	1.5	8.6	9.7	0.6	1
Sugar-cane tops	76.6	1.9	1.3	8.0	11.8	0.4	1
Miscellaneous silage							
Alfalfa	75.4	2.9	3.5	8.2	8.6	1.4	2
Apple pomace	79.4	1.0	1.6	4.5	12.2	1.3	14
Barley	75.0	2.6	2.6	9.4	9.4	1.0	2
Clover	72.2	2.5	3.7	9.0	11.5	1.1	14
Corn and clover	71.4	2.2	3.3	7.7	14.5	0.9	1

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
SILAGE—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Miscellaneous silage—con.							
Corn and rye	80.6	1.4	2.1	7.2	7.5	1.2	1
Corn and soybean	75.3	2.0	2.5	6.7	12.5	1.0	15
Cowpea	78.0	2.2	3.2	6.3	9.4	0.9	9
Cowpea and soybean	71.5	3.5	3.4	8.6	11.9	1.1	2
Field pea	72.1	2.6	3.8	7.8	12.5	1.2	8
Grasses, mixed	69.3	2.5	2.3	9.9	14.6	1.4	5
Millet	68.4	3.4	2.8	9.7	14.6	1.1	6
Millet, barnyard, and soybean	79.0	2.8	2.8	7.2	7.2	1.0	9
Oat	71.7	1.9	2.0	9.8	13.3	1.3	2
Oat and pea	72.5	2.8	3.8	9.6	10.0	1.3	6
Pea-cannery refuse	76.8	1.3	2.8	6.5	11.3	1.3	....
Rye	72.8	2.1	3.0	9.8	11.6	0.7	2
Sorghum and cowpea	67.7	2.2	2.4	8.5	18.2	1.0	8
Soybean	72.9	3.5	3.9	8.1	10.3	1.3	9
Sugar beet leaves	77.0	4.4	2.8	4.7	10.6	0.5	2
Sugar beet pulp	90.0	0.3	1.5	3.1	4.7	0.4	1
Vetch	69.9	2.4	3.5	9.8	13.4	1.0	6
Wet brewers' grains	70.2	1.2	6.4	4.5	15.6	2.1	4

Table II. Average Digestibility of American Feeding Stuffs, with Additions from the German Tables

The coefficients marked "H & M" in this table have been compiled by the authors from the digestion trials reported by the State Experiment Stations and the United States Department of Agriculture. Those marked "L" are from the compilation by Lindsey given in the *Massachusetts (Hatch) Experiment Station Report* for 1911, and unpublished coefficients furnished by him for this edition. To render the table more complete, additions marked "M" have been made from the German tables given in Mentzel and Lengerke's *Landwirtschaftliche Kalender* for 1914.

A. Experiments with Ruminants

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates: Fiber	Carbohydrates: N-free extract	Fat	Authority
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Concentrates							
Grains, seeds, and their products							
Corn meal	12	90	74	57	94	93	H & M
Corn cob	3	54	19	60	52	50	H & M
Corn-and-cob meal	3	79	52	45	88	84	H & M
Hominy feed	9	83	66	76	90	91	H & M
Gluten feed	19	86	85	76	88	85	H & M
Gluten meal	10	88	85	55	90	93	H & M
Germ oil meal	5	76	73	75	78	96	H & M
Corn bran	6	71	60	71	80	80	H & M
Wheat, ground	4	87	74	59	93	72	H & M
Durum wheat	2	..	78	40	92	65	H & M
Flour wheat middlings	4	82	88	36	88	86	L
Standard wheat middlings	6	..	77	30	78	88	L
Wheat bran, av. of all trials	20	65	78	31	72	68	H & M
Wheat bran, winter	3	64	78	28	71	65	H & M
Wheat bran, spring	7	67	76	43	74	62	H & M
Wheat bran, low grade	3	62	63	28	71	92	H & M
Wheat feed	4	73	77	36	76	87	H & M
Wheat screenings	4	63	72	..	73	88	H & M
Rye meal	2	87	84	..	92	64	H & M
Rye feed	3	82	80	..	88	90	H & M
Oats	17	70	78	35	81	87	H & M
Oat feed, low grade	14	50	72	40	55	83	H & M
Oat middlings	2	90	80	49	85	93	H & M
Oat hulls	1	54	50	60	53	77	H & M
Barley	15	88	78	56	92	78	H & M
Barley, ground	2	89	88	70	93	86	H & M
Barley bran	2	..	85	20	86	87	M
Malt sprouts	5	78	77	87	80	85	H & M
Brewers' grains, dried	5	61	81	49	57	89	H & M
Emmer	15	..	80	64	89	88	H & M
Rice meal	2	74	62	..	92	91	H & M
Rice polish	4	82	67	26	91	82	H & M
Rice bran	6	61	65	25	79	77	H & M
Rice hulls	2	16	10	1	35	67	M
Buckwheat	2	71	75	24	76	100	M

TABLE II. Average digestibility of American feeding stuffs — *continued.*

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat	Authority
				Fiber	N-free extract		
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
CONCENTRATES — con.							
Grains, seeds, and their products — con.							
Buckwheat middlings	5	74	87	32	86	83	H & M
Buckwheat bran	..	49	47	39	56	56	H & M
Kafir, ground, with legume hay	2	..	81	55	92	76	H & M
Kafir, in unbalanced ration	15	50	47	44	51	51	H & M
Kafir heads, with legume hay	2	..	63	61	80	74	H & M
Kafir heads, in unbalanced ration	8	34	32	35	36	40	H & M
Milo maize, in unbalanced ration	3	80	57	100	84	88	H & M
Millet seed, whole	6	..	59	41	84	80	H & M
Millet seed, ground	6	..	71	53	92	73	H & M
Cotton seed	2	66	68	76	50	87	H & M
Cotton seed, roasted	2	56	47	66	51	72	H & M
Cottonseed meal, choice and prime	15	77	84	37	75	95	H & M
Cold-pressed cottonseed cake	4	..	81	48	72	96	H & M
Cottonseed feed	34	56	58	45	61	90	H & M
Cottonseed hulls	13	41	6	47	34	79	L
Flax seed	7	77	91	60	55	86	M
Linseed meal, old process	3	79	89	57	78	89	H & M
Linseed meal, new process	4	81	86	73	87	95	H & M
Cowpea meal	2	87	82	64	93	74	H & M
Horse beans	30	..	87	58	91	83	M
Pea meal	2	87	83	26	94	55	H & M
Pea hulls	4	..	71	94	90	73	M
Peanut cake, from hulled nuts	7	..	90	9	84	90	M
Peanut cake, many hulls	2	32	71	12	49	90	H & M
Soybeans, ground	15	88	84	81	73	82	M
Soybean meal, fat extracted	2	..	92	99	100	68	M
Cocoanut cake	3	82	90	23	87	100	H & M
Palmnut cake	4	..	74	55	93	100	M
Rapeseed cake	7	..	81	8	76	79	M
Sesame oil cake	8	..	92	73	71	94	M
Sunflower seed cake	6	..	92	26	71	90	M
Slaughter house and animal by-products							
Skim milk	3	98	94	..	98	98	H & M
Dried blood	2	..	84	..	..	..	H & M
Fish meal	4	71	78	..	..	100	H & M
Flesh meal	5	..	93	..	..	98	M
Miscellaneous concentrates							
Beet pulp, dried	3	75	52	83	83	..	H & M
Beet pulp, molasses-	5	83	62	80	91	..	H & M
Cocoa shells	2	58	11	51	73	100	H & M
Distillers' grains, largely from corn	17	79	73	95	81	95	L
Distillers' grains, largely from rye	2	58	59	..	67	84	L
Molasses, cane, or black-strap	26	78	32	..	90	..	H & M
Molasses feeds	8	68	61	50	79	100	H & M
DRIED ROUGHAGE							
Cured corn and sorghum forage							
Corn fodder, dent, mature	30	66	45	63	73	70	L
Corn fodder, dent, in milk	11	63	50	64	66	75	L
Corn fodder, southern dent, immature	4	57	27	59	61	76	L
Corn fodder, flint, mature	11	70	64	76	71	71	L
Corn fodder, flint, ears forming	3	70	70	72	71	67	L

TABLE II. Average digestibility of American feeding stuffs — *continued.*

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat	Authority
				Fiber	N-free extract		
DRIED ROUGHAGE — con.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Cured corn and sorghum forage — con.							
Sweet corn fodder	6	67	64	74	68	74	H & M
Corn stover	35	57	37	66	59	62	H & M
Corn leaves	4	60	45	69	63	59	H & M
Corn husks	5	..	19	73	66	36	H & M
Corn stover, tops and leaves	2	60	55	71	62	71	H & M
New corn product	3	63	60	61	66	83	H & M
Kafir fodder	8	59	46	60	67	60	H & M
Kafir stover	5	56	34	67	60	75	H & M
Milo fodder	3	52	16	51	61	63	H & M
Sorghum fodder	20	58	38	61	63	65	H & M
Sorghum bagasse	1	61	14	64	65	46	H & M
Hay from the grasses, etc.							
Bermuda grass	9	54	52	52	51	42	H & M
Black grass	5	56	58	59	52	44	H & M
Bluegrass, Canada	2	62	43	70	62	37	H & M
Bluegrass, Kentucky	7	56	57	66	61	52	H & M
Brome grass	11	63	51	59	64	39	H & M
Brome grass, western	2	60	68	53	67	16	H & M
Buffalo grass	3	..	54	61	60	45	H & M
Bunch grass, black	4	..	20	54	47	37	H & M
Chess, or cheat	1	45	42	46	49	32	H & M
Crab grass, ripe	8	53	44	60	53	43	H & M
Fescue, meadow	2	61	52	67	59	54	H & M
Johnson grass	9	57	44	67	57	46	H & M
Millet, barnyard	4	59	61	64	56	47	H & M
Millet, Hungarian	2	65	60	68	67	64	H & M
Millet, pearl, or cat-tail	2	62	63	67	59	46	H & M
Mixed grasses, 8–10% protein	73	61	57	62	62	50	L
Mixed grasses, low in protein	34	..	50	55	59	49	M
Oat grass, tall	4	52	43	56	52	46	H & M
Orchard grass	3	58	60	61	56	55	H & M
Quack, or couch grass	3	62	57	61	67	56	H & M
Para grass	3	..	..	53	47	45	H & M
Prairie grass, western	16	..	..	58	53	42	H & M
Red top	3	60	62	61	63	53	H & M
Rush, Baltic	2	67	74	71	61	49	H & M
Salt grasses	5	54	45	59	53	35	H & M
Salt bushes	6	51	75	14	56	41	H & M
Sedges, western	2	62	62	70	65	42	H & M
Spear grasses	1	62	62	71	60	43	H & M
Timothy, av. of all trials	58	55	48	50	62	50	L
Timothy, in bloom	8	59	57	57	63	48	L
Timothy, past bloom	17	52	43	46	59	51	L
Wheat grasses, miscellaneous	6	55	62	58	57	34	H & M
Wheat grass, western	10	64	55	69	63	41	H & M
Hay from the smaller cereals							
Barley	4	59	65	62	63	41	H & M
Oat	22	54	54	52	56	61	H & M
Hay from the legumes							
Alfalfa, av. of all trials	109	60	71	43	72	38	H & M
Alfalfa, first cutting	53	59	67	42	72	38	H & M
Alfalfa, second cutting	21	62	76	44	74	40	H & M

TABLE II. Average digestibility of American feeding stuffs — *continued.*

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat	Authority
				Fiber	N-free extract		
DRIED ROUGHAGE — con.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Hay from the legumes — con.							
Alfalfa, third cutting	6	58	70	40	70	42	H & M
Alfalfa, budded to full bloom	74	60	70	43	72	39	H & M
Clover, alsike	15	56	62	48	64	43	H & M
Clover, bur	2	..	81	64	76	5	H & M
Clover, crimson	13	62	69	47	65	44	H & M
Clover, red, av. of all trials	25	59	59	54	66	57	H & M
Clover, red, in bloom	4	62	62	53	68	54	H & M
Clover rowen	4	..	65	47	63	60	H & M
Clover, sweet, white	3	61	75	34	72	31	H & M
Clover, white	1	66	73	61	70	51	H & M
Cowpea	4	59	68	47	68	39	H & M
Lupine, wild	2	68	75	56	75	57	H & M
Peanut vine	5	60	72	52	72	80	H & M
Sanfoin	2	..	70	36	74	66	M
Serradella	2	..	75	50	63	65	M
Soybean	4	60	73	57	64	44	H & M
Vetch, common	5	65	67	57	72	64	H & M
Vetch, hairy	8	67	79	59	71	67	H & M
Hay from mixed grasses and legumes							
Clover and mixed grasses, western	8	68	55	72	70	70	H & M
Clover and timothy	13	55	47	51	60	45	H & M
Peas and oats	7	62	73	58	61	59	H & M
Vetch and oats	7	58	65	55	59	55	H & M
Vetch and wheat	6	66	74	65	68	64	H & M
Straw and chaff							
Barley straw	7	..	25	54	53	39	M
Flax shives	2	45	81	26	43	93	H & M
Horse bean straw	5	..	49	43	68	57	H & M
Oat straw	18	54	28	60	51	39	H & M
Oat chaff	2	..	38	45	49	48	M
Rice straw	6	..	22	59	46	23	H & M
Rye straw	9	..	23	55	39	36	M
Soybean straw	4	..	50	38	66	60	M
Wheat straw	10	..	23	50	37	31	M
Wheat chaff	3	..	26	39	33	43	M
FRESH GREEN ROUGHAGE							
Corn and the sorghums							
Corn fodder, dent, immature	14	68	66	65	71	86	L
Corn fodder, dent, in milk	17	70	62	64	77	76	L
Corn fodder, dent, mature	23	69	54	59	75	75	L
Corn fodder, flint, mature	4	69	52	75	71	66	L
Corn fodder, sweet, in milk	2	77	78	75	81	74	H & M
Corn fodder, sweet, roasting ears	12	..	62	60	77	75	H & M
Sorghum fodder, all trials	6	65	44	55	73	64	L
Sorghum fodder, in bloom	2	68	47	62	75	70	L
Fresh green grasses and cereals							
Barley	6	..	71	59	72	56	H & M
Bluegrass, native	2	53	64	45	60	50	H & M
Brome grass, western	2	60	68	53	67	16	H & M
Millet, barnyard	9	70	60	69	70	62	H & M
Millet, Hungarian	8	63	64	70	67	62	H & M
Mixed grasses, immature	2	..	70	66	75	62	M

TABLE II. Average digestibility of American feeding stuffs — *continued.*

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat	Authority
				Fiber	N-free extract		
FRESH GREEN ROUGHAGE — con.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Fresh green grasses and cereals — con.							
Mixed grasses, late in season	4	..	56	62	61	46	M
Oat fodder	5	..	73	55	63	70	H & M
Orchard grass	3	..	60	60	55	54	M
Red top	3	..	61	61	62	50	M
Rye fodder	2	74	79	80	71	74	H & M
Timothy	3	63	48	56	66	53	H & M
Green legumes							
Alfalfa	2	61	74	42	72	38	H & M
Clover, crimson	3	..	77	56	74	66	H & M
Clover, red	2	66	67	53	78	65	H & M
Clover rowen	2	..	62	53	65	61	H & M
Cowpea	4	68	76	60	81	59	H & M
Lupine	2	68	75	56	76	57	L
Pea, field, Canada	8	63	81	49	74	54	H & M
Sanfoin	2	..	73	42	78	67	M
Soybean, all trials	23	64	77	45	75	53	H & M
Soybean, in bloom	2	..	77	47	71	50	H & M
Vetch, common	2	62	71	44	76	59	H & M
Vetch, hairy	14	71	83	64	77	72	H & M
Mixed legumes and grasses							
Peas and barley	4	..	75	52	68	59	H & M
Peas and oats	10	70	74	59	68	64	H & M
Vetch and oats	3	67	75	68	68	47	H & M
Vetch and wheat	5	69	74	68	73	57	H & M
Roots and tubers							
Beet, sugar	30	..	72	34	97	..	M
Carrot	5	86	76	100	94	100	L
Mangel	6	84	59	78	94	..	H & M
Potato	30	..	51	..	90	..	M
Rutabaga	2	87	80	74	95	84	H & M
Turnip	10	..	73	51	92	..	M
Miscellaneous green forages							
Cabbage	4	93	86	100	99	56	L
Cabbage waste, outer leaves	2	74	64	78	84	37	L
Cactus, prickly pear	4	65	50	47	81	68	H & M
Kale	4	68	81	59	76	66	H & M
Pumpkin	7	81	77	61	89	92	L
Rape	4	86	89	87	92	49	H & M
SILAGE							
Corn, dent, mature	27	66	51	65	71	82	L
Corn, dent, immature	17	64	53	68	66	71	L
Clover	5	43	34	48	45	45	H & M
Corn and soybean	8	69	63	62	77	83	H & M
Cowpea	4	60	57	52	73	63	H & M
Kafir, well matured	3	55	..	57	62	50	L
Millet, barnyard, and soybean	4	59	57	69	59	72	L
Oat and pea	2	65	75	61	67	75	H & M
Sorghum, well matured	3	57	..	58	64	56	L
Soybean	7	56	66	53	65	57	L
Vetch	2	63	56	63	67	77	H & M

TABLE II. Average digestibility of American feeding stuffs — *continued.*

B. Experiments with Horses

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat	Authority
				Fiber	N-free extract		
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Corn	2	74	58	..	83	48	H & M
Corn meal	2	88	76	..	96	73	H & M
Oats	34	..	80	29	75	71	M
Timothy hay	2	44	21	43	47	47	H & M
Meadow hay, excellent	4	..	63	48	65	22	M
Meadow hay, good	14	..	58	39	58	18	M
Meadow hay, poor	12	..	55	38	52	29	M
Alfalfa hay	6	..	73	46	70	14	M
Clover hay, red	5	..	56	37	63	29	M

C. Experiments with Calves

Whole milk	13	..	94	..	98*	97	H & M
Pasteurized whole milk	9	..	93	..	98*	96	H & M
Cooked whole milk	3	..	87	..	98*	95	H & M
Skim milk	3	..	95	..	98*	..	H & M

D. Experiments with Swine

Shelled corn	33	87	75	44	92	64	H & M
Ground corn	47	87	76	46	93	64	H & M
Corn-and-cob meal	1	76	76	28	84	82	H & M
Wheat	2	..	80	60	83	70	M
Red dog flour	2	87	88	..	..	36	H & M
Wheat middlings (shorts)	9	82	83	30	86	83	H & M
Wheat bran	2	66	75	39	66	72	M
Barley	29	..	77	12	89	44	M
Rye	4	..	84	10	94	41	M
Sorghum seed	9	..	60	20	83	72	M
Broom-corn millet seed	1	73	68	33	92	59	H & M
Rice	2	..	86	..	100	70	M
Pea meal	11	..	90	70	96	49	M
Linseed meal, old process	9	78	85	16	82	70	H & M
Soybean meal	5	..	84	30	100	84	H & M
Skim milk	5	..	100	..	100	100	H & M
Dried blood	1	72	72	..	92	..	M
Tankage	5	..	71	..	100	100	H & M
Pork cracklings	20	100	94	..	..	100	H & M
Potato	4	97	84	..	98	..	L

*Assumed.

Table III. Average Digestible Nutrients and Fertilizing Constituents in American Feeding Stuffs

The data for the digestible nutrients in this table are derived by combining the data in the two preceding tables, according to the method described in Article **69** of the text. Where no digestion coefficients are available for any feed, the digestion coefficients for a similar feed have been used and that fact indicated by an asterisk. The total digestible nutrients given in the fifth column is the sum of the digestible crude protein, the digestible carbohydrates, and the digestible fat × 2.25. (**69-70**) For the convenience of the student and farmer in computing rations, the sixth column, showing the nutritive ratio of each feeding stuff, has been added to the table.

The fertilizing constituents given are mostly from an exhaustive compilation by the authors of the analyses reported by the State Experiment Stations and the United States Department of Agriculture. A few values have been taken from Mentzel and Lengerke's, *Landwirtschaftliche Kalender* for 1914, and other sources.

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbo-hydrates	Fat	Total		Nitro-gen	Phos-phoric acid	Potash
Concentrates	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Corn and its products									
Dent corn	89.5	7.5	67.8	4.6	85.7	10.4	16.2	6.9	4.0
Flint corn	87.8	7.7	66.1	4.6	84.2	9.9	16.6	6.8	3.9
Soft corn	69.4	5.5	53.3	3.5	66.7	11.1	11.8	5.4	3.1
Sweet corn *	90.7	8.5	64.5	7.3	89.4	9.5	18.4	...	...
Pop corn *	90.6	9.0	66.7	4.8	86.5	8.6	19.4	...	...
Corn meal or chop	88.7	6.9	69.0	3.5	83.8	11.1	14.9	6.1	3.7
Corn cob	90.0	0.4	47.3	0.2	48.1	119.2	3.2	0.7	6.6
Corn-and-cob meal	89.6	6.1	63.7	3.7	78.1	11.8	13.8	5.8	6.3
Hominy feed, high grade	89.9	7.0	61.2	7.3	84.6	11.1	17.0	12.4	9.5
Hominy feed, low grade *	90.9	6.3	64.1	5.6	83.0	12.2	15.2	12.5	9.6
Hominy, pearled *	89.4	5.8	72.1	3.1	84.9	13.6	12.5	2.3	1.6
Gluten feed, high grade	91.3	21.6	51.9	3.2	80.7	2.7	40.6	6.2	2.3
Gluten feed, low grade *	91.2	15.1	57.8	4.8	83.7	4.5	28.5	6.2	2.3
Gluten meal, high grade	90.9	30.2	43.9	4.4	84.0	1.8	56.8	5.5	1.2
Gluten meal, low grade *	91.8	23.2	44.1	9.7	89.1	2.8	43.7	5.6	1.2
Germ oil meal, high grade	91.1	16.5	42.6	10.4	82.5	4.0	36.2	13.2	2.5
Germ oil meal, low grade *	92.2	10.0	50.3	10.0	82.8	7.3	21.9	13.3	2.5
Corn bran	90.0	5.8	56.9	4.6	73.1	11.6	15.5	6.2	5.4
Wheat and its products									
Wheat, all analyses	89.8	9.2	67.5	1.5	80.1	7.7	19.8	8.6	5.3
Wheat, Atlantic states	88.8	8.7	67.5	1.4	79.4	8.1	18.7	8.5	5.2
Wheat, Minn., N. D., S. D., Nebr., Kan.	89.6	10.0	66.3	1.5	79.7	7.0	21.6	8.6	5.2
Wheat, Miss. valley, except above states	89.5	9.1	67.5	1.4	79.8	7.8	19.7	8.6	5.2
Wheat, Rocky Mountain states	91.5	9.8	68.1	1.6	81.5	7.3	21.3	8.7	5.4
Wheat, Pacific states	89.1	7.3	69.1	1.4	79.6	9.9	15.8	8.5	5.2

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
CONCENTRATES—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Wheat and its products—con.									
Winter wheat	89.1	8.7	67.8	1.4	79.7	8.2	18.7	8.5	5.2
Spring wheat	89.9	9.2	67.2	1.6	80.0	7.7	20.0	8.6	5.3
Durum wheat	89.6	11.0	64.2	1.6	78.8	6.2	22.6	8.6	5.2
Polish wheat *	90.5	15.0	60.9	1.2	78.6	4.2	32.5	8.6	5.3
Wheat flour, patent *	87.7	8.1	69.6	0.9	79.7	8.8	17.4	2.0	1.0
Wheat flour, graham *	88.0	12.1	61.2	1.8	77.3	5.4	21.9	6.4	4.0
Red dog flour *	88.9	14.8	56.5	3.5	79.2	4.4	26.9	20.0	7.6
Flour wheat middlings	89.3	15.7	52.8	4.3	78.2	4.0	28.5	....	...
Standard wheat middlings (shorts)	89.5	13.4	46.2	4.3	69.3	4.2	27.7	21.1	11.8
Wheat bran, all analyses	89.9	12.5	41.6	3.0	60.9	3.9	25.6	29.5	16.2
Wheat bran, winter	89.4	12.2	40.9	2.9	59.6	3.9	25.1	29.3	16.1
Wheat bran, spring	89.6	11.9	43.3	3.0	62.0	4.2	25.1	29.4	16.2
Wheat bran, low grade *	90.0	7.5	41.4	3.3	56.3	6.5	19.0	29.5	16.2
Wheat feed (shorts and bran)	89.9	12.9	45.1	4.0	67.0	4.2	26.9	21.9	8.8
Wheat screenings	89.8	9.6	47.3	3.6	65.0	5.8	21.3	7.4	7.6
Rye and its products									
Rye	90.6	9.9	68.4	1.2	81.0	7.2	18.9	7.3	5.7
Rye meal or chop	89.0	9.2	67.6	1.3	79.7	7.7	17.4	8.3	5.2
Rye flour *	88.2	6.6	72.0	0.7	80.2	11.2	12.6	...	...
Rye middlings *	88.6	12.6	55.5	3.1	75.1	5.0	25.1	5.6	4.9
Rye bran *	88.6	12.2	56.6	2.8	75.1	5.2	24.5	15.4	9.6
Rye feed (shorts and bran)	88.5	12.2	55.8	2.9	74.5	5.1	24.5	5.6	4.6
Oats and oat products									
Oats	90.8	9.7	52.1	3.8	70.4	6.3	19.8	8.1	5.6
Oats, light weight *	91.3	9.6	49.5	4.1	68.3	6.1	19.7	8.2	5.7
Oat kernel, without hull *	93.1	11.4	57.7	7.5	86.0	6.5	22.9	...	...
Oat meal *	92.1	12.8	56.9	6.0	83.2	5.5	25.6	...	...
Ground oats, high grade *	89.2	9.4	51.4	4.1	70.0	6.4	19.4	8.0	5.6
Oat feed, low grade	89.8	6.9	37.0	3.2	51.1	6.4	15.4	5.9	6.3
Oat middlings	92.7	13.0	54.9	6.3	82.1	5.3	26.1	12.7	6.9
Oat bran *	93.6	8.8	36.1	3.9	53.7	5.1	19.5	....	...
Oat dust *	93.4	9.1	34.9	4.3	53.7	4.9	20.2	....	...
Oat hulls	93.2	2.0	45.2	1.3	50.1	24.1	6.4	2.1	5.8
Corn and oat feed, high grade *	88.6	7.3	60.6	3.4	75.6	9.4	15.4	7.5	4.8
Corn and oat feed, low grade *	90.5	6.0	52.4	3.1	65.4	9.9	14.2	5.7	5.1
Barley, its products, and emmer									
Barley	90.7	9.0	66.8	1.6	79.4	7.8	18.4	8.5	7.4
Barley, bald *	90.6	8.4	67.5	2.0	80.4	8.6	17.3	...	...
Barley feed *	89.8	10.8	54.6	3.0	72.2	5.7	20.3	12.8	8.9
Barley shorts *	89.8	11.0	52.5	3.4	71.2	5.5	20.6	....	...
Barley bran	93.4	7.7	52.4	2.4	65.5	7.5	14.6	9.7	8.8
Barley screenings *	88.6	8.3	47.7	2.5	61.6	6.4	18.4	...	...
Malt *	94.2	15.8	62.7	3.2	85.7	4.4	28.8	9.5	4.5
Malt sprouts	92.4	20.3	47.4	1.3	70.6	2.5	42.2	16.5	18.3
Brewers' grains, dried	92.5	21.5	30.5	6.1	65.7	2.1	42.4	9.9	0.9
Brewers' grains, dried, below 25% protein *	91.8	18.7	32.1	5.7	63.6	2.4	37.0	9.8	0.9
Brewers' grains, wet *	24.1	4.6	8.7	1.5	16.7	2.6	9.1	2.4	0.3
Emmer (spelt)	91.3	9.5	63.2	1.7	76.5	7.1	19.0	7.6	5.7
Emmer, without hulls *	89.5	11.9	62.3	2.2	79.2	5.7	23.8	...	...

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbo-hydrates	Fat	Total		Nitro-gen	Phos-phoric acid	Potash
CONCENTRATES — con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Rice and its products									
Rough rice *	90.4	4.7	64.6	1.7	73.1	14.6	12.2	4.9	2.6
Polished rice *	87.7	4.6	72.8	0.4	78.3	16.0	11.8	1.7	0.6
Rice polish	90.0	8.0	57.2	7.5	82.1	9.3	19.0	30.8	11.7
Rice bran, high grade	89.9	7.9	38.1	8.8	65.8	7.3	19.4	22.2	12.0
Rice bran, low grade	90.5	7.1	37.7	7.5	61.7	7.7	17.4	22.6	12.2
Rice meal	90.5	7.3	48.1	10.6	79.2	9.8	18.9	....	....
Rice hulls	90.7	0.3	12.3	0.7	14.2	46.3	5.3	0.9	2.2
Buckwheat and its products									
Buckwheat	87.9	8.1	49.7	2.5	63.4	6.8	17.3	10.0	7.0
Buckwheat flour *	87.2	5.9	58.0	1.5	67.3	10.4	12.6	4.4	1.9
Buckwheat middlings	88.0	24.6	38.3	6.1	76.6	2.1	45.3	23.4	11.8
Buckwheat bran, high grade	88.8	10.5	30.4	3.2	48.1	3.6	35.7	16.5	10.0
Buckwheat bran, low grade *	89.9	2.4	21.4	1.7	27.6	10.5	17.1	9.4	9.1
Buckwheat feed, good grade *	88.2	9.1	30.2	2.9	45.8	4.0	30.9	11.0	7.9
Buckwheat feed, low grade *	88.1	3.7	24.0	2.1	32.4	7.8	21.3	8.4	8.2
Buckwheat hulls *	89.7	0.4	13.9	0.7	15.9	38.8	7.0	5.7	8.6
The sorghums, etc.									
Kafir grain	88.2	9.0	65.8	2.3	80.0	7.9	17.8	5.7	3.1
Kafir-head chops	87.5	6.1	56.6	2.0	66.7	9.9	15.5	...	...
Milo grain *	89.3	8.7	66.2	2.2	79.9	8.2	17.1	7.8	4.3
Milo-head chops *	89.7	6.3	58.1	1.9	68.7	9.9	16.0	...	...
Feterita grain *	89.2	9.3	66.6	2.5	81.5	7.8	18.4	...	...
Durra grain *	90.1	8.2	67.9	2.7	82.2	9.0	16.2	...	...
Shallu grain *	90.3	10.1	66.3	2.6	82.2	7.1	20.0	...	...
Kaoliang grain *	90.1	8.5	67.0	3.3	82.9	8.8	16.8	...	...
Sorghum grain *	87.3	7.5	66.2	2.6	79.5	9.6	14.7	8.2	3.3
Broom-corn seed *	88.2	8.3	62.9	2.6	77.0	8.3	16.3	...	...
Hog, or broom-corn, millet seed	90.9	8.4	63.7	2.4	77.5	8.2	18.9	7.2	5.2
Foxtail millet seed	89.2	8.6	60.6	3.0	76.0	7.8	19.4	4.6	3.7
Barnyard millet seed *	89.8	7.6	57.0	3.4	72.2	8.5	17.1	...	...
Pearl millet seed	92.0	8.3	64.7	4.9	84.0	9.1	18.7	...	...
Cotton seed and its products									
Cotton seed	90.6	13.3	29.6	16.5	80.0	5.0	31.2	15.0	15.0
Cottonseed meal, choice	92.5	37.0	21.8	8.6	78.2	1.1	70.6	26.7	18.1
Cottonseed meal, prime	92.2	33.4	24.3	7.9	75.5	1.3	63.7	26.6	18.0
Cottonseed meal, good *	92.1	31.6	25.6	7.8	74.8	1.4	60.2	26.6	18.0
Cold-pressed cottonseed cake	92.1	21.1	33.2	7.4	70.9	2.4	41.8	....	...
Cottonseed feed	91.7	14.2	30.7	5.7	57.7	3.1	39.2	14.7	14.7
Cottonseed hulls	90.3	0.3	33.3	1.5	37.0	122.3	7.4	3.6	12.8
Cottonseed-hull bran *	91.6	0.2	33.3	0.9	35.5	176.5	5.4	...	....
Flaxseed and its products									
Flax seed	90.8	20.6	17.0	29.0	102.8	4.0	36.2	15.0	9.5
Linseed meal, old process	90.9	30.2	32.6	6.7	77.9	1.6	54.2	17.0	12.7
Linseed meal, new process	90.4	31.7	37.9	2.8	75.9	1.4	59.0	17.7	13.0
Flax feed *	90.6	12.0	34.2	12.5	74.3	5.2	26.6	....	...
Flax screenings *	91.4	11.1	35.1	10.4	69.6	5.3	24.6	3.5	12.6
Leguminous seeds and their products									
Adzuki bean *	86.0	17.4	54.3	0.4	72.6	3.2	33.6	...	....
Bean, navy *	86.6	18.8	51.3	0.8	71.9	2.8	36.3	7.8	13.7

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
CONCENTRATES — con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Leguminous seeds and their products—con.									
Bean, navy, cull *	87.2	18.3	54.3	0.8	74.4	3.1	35.4	...	...
Cowpea	88.4	19.4	54.5	1.1	76.4	2.9	37.8	10.1	14.9
Frijole *	90.4	20.4	53.8	0.6	75.6	2.7	39.4	....	....
Horse bean	87.4	22.8	49.1	0.7	73.5	2.2	41.9	12.4	13.4
Jack bean *	88.5	20.7	50.9	2.2	76.6	2.7	38.1	....	....
Pea, field	90.8	19.0	55.8	0.6	76.2	3.0	36.6	8.4	10.1
Pea, garden	88.2	21.2	51.5	0.9	74.7	2.5	41.0	...	....
Pea meal	89.1	19.8	53.6	0.8	75.2	2.8	38.1	9.2	10.0
Pea bran *	90.1	8.7	65.2	0.8	75.7	7.7	19.5	3.1	10.3
Pea hulls	92.8	4.9	74.7	0.9	81.6	1.6	11.0	...	....
Peanut, with hull *	93.5	18.4	15.3	32.6	107.1	4.8	32.6	7.6	6.4
Peanut kernel, without hull *	94.0	24.1	14.9	40.4	129.9	4.4	42.9	10.1	6.5
Peanut waste *	96.0	22.0	22.9	30.1	112.6	4.1	39.0	....	...
Peanut cake, from hulled nuts	89.3	42.8	20.4	7.2	79.4	0.9	76.2	11.6	10.0
Peanut cake, hulls included	94.4	20.2	16.0	10.0	58.7	1.9	45.4	....	....
Peanut hulls *	90.9	0.4	33.0	2.1	38.1	94.2	11.7	1.4	7.4
Sesbania macrocarpa *	90.8	27.6	42.4	3.6	78.1	1.8	50.7	...	...
Soybean	90.1	30.7	22.8	14.4	85.9	1.8	58.4	13.7	24.7
Soybean meal, fat extracted	88.2	38.1	33.9	5.0	83.2	1.2	66.2	....	....
Tepary *	90.5	18.4	56.6	0.8	76.8	3.2	35.5	....	....
Velvet bean, seed *	88.3	18.1	50.8	5.3	80.8	3.5	33.3	....	....
Velvet bean, seed and pod *	87.7	14.9	51.7	3.8	75.2	4.0	27.4	....	....
Miscel. oil-bearing seeds and their products									
Cocoanut meal, low in fat	90.4	18.8	42.0	8.1	79.0	3.2	33.4	12.5	23.7
Cocoanut meal, high in fat	92.3	18.4	37.6	17.1	94.5	4.1	32.6	7.8	24.2
Palmnut cake	89.6	12.4	45.8	9.5	79.6	5.4	26.9	11.0	5.0
Rapeseed cake	90.0	25.3	23.7	7.6	66.1	1.6	49.9	20.3	13.2
Sesame oil cake	90.2	34.5	20.0	13.2	84.2	1.4	60.0	33.2	14.7
Sunflower seed, with hulls *	93.1	13.5	38.1	20.3	97.3	6.2	25.8	12.2	5.6
Sunflower seed, without hulls *	95.5	23.3	17.0	33.9	116.6	4.0	44.3	....	...
Sunflower seed cake	90.0	32.0	18.3	16.5	87.4	1.7	55.7	21.6	11.7
Milk and its products									
Cow's milk	13.6	3.3	4.9	4.3	17.9	4.4	5.6	1.9	1.7
Cow's milk, colostrum	25.5	16.5	2.6	3.5	27.0	0.6	28.2	6.6	1.1
Skim milk, centrifugal	9.9	3.6	5.1	0.2	9.1	1.5	6.1	2.2	1.7
Skim milk, gravity	9.6	3.1	4.6	0.9	9.7	2.1	5.3	2.2	1.7
Skim milk, dried *	91.7	34.4	25.3	4.1	68.9	1.0	58.6	...	...
Buttermilk *	9.4	3.4	4.9	0.1	8.4	1.5	5.8	1.7	1.6
Whey *	6.6	0.8	4.7	0.3	6.2	6.8	1.6	1.2	2.6
Slaughter house by-products									
Dried blood	90.3	69.1	...	0.9	71.1	0.03	131.5	4.9	1.2
Fish meal, high in fat	89.2	37.8	...	11.6	63.9	0.7	77.4	140.0	3.0
Fish meal, low in fat	87.2	40.9	...	2.2	45.9	0.1	83.8	....	...
Fish-glue waste *	86.0	30.5	...	7.9	48.3	0.6	62.6	....	...
Fresh bone *	69.6	18.3	...	24.5	73.4	3.0	31.5	....	...
Meat-and-bone meal, 30–40% ash *	94.0	37.0	...	11.0	61.8	0.7	63.7	....	...
Meat-and-bone meal, over 40% ash *	93.4	30.9	...	9.8	53.0	0.7	53.1	....	...

Table III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
Concentrates — con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Slaughter house by-products—con.									
Pork cracklings *	95.0	52.4	...	32.6	125.8	1.4	90.2	6.1	...
Poultry bone *	92.7	22.6	...	3.0	29.4	0.3	38.9	....	...
Tankage, over 60% protein *	92.6	58.7	...	12.6	87.0	0.5	101.0	55.8	5.5
Tankage, 55–60% protein *	92.5	54.0	...	12.7	82.6	0.5	93.0	...	...
Tankage, 45–55% protein *	92.5	48.1	...	13.7	78.9	0.6	82.7	101.5	...
Tankage, below 45% protein *	93.5	37.6	...	16.7	75.2	1.0	64.6	135.7	...
Miscellaneous concentrates									
Acorn, kernel and shell *	72.1	2.3	36.2	3.8	47.1	19.5	5.4	...	...
Acorn, kernel *	65.6	2.9	27.3	4.7	40.8	13.1	6.7	...	...
Beet pulp, wet *	9.3	0.5	6.5	0.2	7.4	13.8	1.4	0.4	0.7
Beet pulp, dried	91.8	4.6	65.2	0.8	71.6	14.6	14.2	2.4	3.8
Beet pulp, molasses-	92.4	5.9	68.0	0.6	75.3	11.8	15.2	1.5	18.1
Bakery refuse *	91.7	8.3	60.8	7.0	84.9	9.2	17.9	...	...
Bread *	66.2	5.8	51.9	0.5	58.8	9.1	12.6	2.0	1.2
Cassava, dried *	94.4	1.4	77.4	0.2	79.2	55.6	4.5	...	...
Cassava starch refuse *	88.0	0.5	56.4	0.6	58.3	115.6	1.3	0.6	2.8
Chess, or cheat seed *	92.3	6.2	60.6	1.5	70.2	10.3	16.8	...	...
Cocoa shells	95.1	1.7	44.8	3.0	53.3	30.4	24.6	13.4	26.0
Corn, oat, and barley feed *	90.3	9.1	59.9	4.0	78.0	7.6	18.2	...	...
Distillers' grains, dried, from corn	93.4	22.4	40.4	11.6	88.9	3.0	49.1	6.8	1.7
Distillers' grains, dried, from rye	92.8	13.6	38.0	6.6	66.4	3.9	37.0	8.3	2.4
Distillers' grains, wet *	22.6	3.3	13.3	1.5	20.0	5.1	7.2	1.6	0.4
Distillery slop, whole *	6.2	1.4	2.8	0.6	5.6	3.0	3.0	1.3	0.7
Distillery slop, strained *	4.1	1.0	1.4	0.7	4.0	3.0	2.2	...	...
Lamb's-quarter seed *	90.2	10.2	40.6	6.9	66.3	5.5	22.6	...	...
Molasses, beet *	74.7	1.1	59.4	...	60.5	54.0	5.6	0.5	56.3
Molasses, cane, or blackstrap	74.2	1.0	58.2	...	59.2	58.2	5.0	2.4	31.6
Molasses feeds, below 10% fiber	88.4	8.2	47.2	5.0	66.6	7.1	21.4	8.4	20.6
Molasses feeds, 10–15% fiber	88.3	7.4	47.7	4.2	64.5	7.7	19.5	8.4	20.6
Molasses feeds, over 15% fiber *	90.7	8.4	45.5	2.8	60.2	6.2	21.9	...	...
Molasses-alfalfa feeds *	86.5	8.5	41.0	0.5	50.6	5.0	19.2	...	...
Molassine meal *	83.4	5.4	50.3	0.8	57.5	9.6	14.1	...	...
Mustard feed or bran *	94.3	22.8	28.7	10.2	74.5	2.3	50.7	...	...
Pigeon-grass seed *	89.3	8.5	45.4	4.3	63.6	6.5	23.0	...	...
Pigweed seed *	93.7	10.8	43.8	6.0	68.1	5.3	24.0	...	...
Potato flakes, dried *	87.9	3.6	67.2	0.2	71.2	18.8	11.4	...	...
Potato flour *	89.4	1.4	73.9	0.4	76.2	53.4	4.3	...	...
Starch feed, dry *	90.7	11.2	55.0	6.6	81.0	6.2	24.6	2.2	0.7
Starch feed, wet *	33.4	4.1	20.0	3.1	31.1	6.6	9.0	0.8	0.2
Starch refuse *	89.7	4.6	66.1	1.3	73.6	15.0	10.1	2.9	1.5
Dried Roughage									
Cured corn and sorghum forage, etc.									
Corn fodder (ears, if any, remaining), very dry, from barn or in arid districts	91.0	3.5	51.7	1.5	58.6	15.7	12.5	3.7	9.9
Corn fodder, medium in water	81.7	3.0	47.3	1.5	53.7	16.9	10.7	3.3	8.9
Corn fodder, high in water	60.7	2.2	35.5	1.0	39.9	17.1	7.7	2.5	6.6
Sweet corn fodder	87.7	5.9	47.6	1.3	56.4	8.6	14.7	4.0	11.8
Corn stover (ears removed), very dry	90.6	2.2	47.8	1.0	52.2	22.7	9.4	4.5	12.9

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbo-hydrates	Fat	Total		Nitro-gen	Phos-phoric acid	Potash
DRIED ROUGHAGE—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Cured corn and sorghum forage, etc.—con.									
Corn stover, medium in water	81.0	2.1	42.4	0.7	46.1	21.0	9.1	4.0	11.5
Corn stover, high in water	59.0	1.4	31.1	0.6	33.9	23.2	6.2	2.9	8.3
Corn leaves	76.6	3.2	40.1	1.1	45.8	13.3	11.4	...	...
Corn husks	75.3	0.6	47.3	0.3	48.6	80.0	4.6	2.3	10.2
Corn tops	82.1	3.1	45.5	1.1	51.1	15.5	9.0	...	...
New corn product	90.8	3.8	49.8	2.3	58.8	14.5	10.2	...	...
Kafir fodder, dry	91.0	4.1	45.0	1.7	52.9	11.9	14.2	...	...
Kafir fodder, high in water	71.7	3.0	38.2	1.6	44.8	13.9	10.4	...	...
Kafir stover, dry	83.7	1.7	43.1	1.3	47.7	27.1	8.2	...	...
Kafir stover, high in water	72.7	1.3	37.8	1.0	41.3	30.8	6.1	...	...
Milo fodder, dry	88.9	1.9	36.3	2.8	44.5	22.4	19.2	...	...
Milo fodder, high in water	60.9	0.6	29.8	1.4	33.6	55.0	5.9	...	...
Milo stover, high in water *	64.5	0.4	31.3	0.5	32.8	81.0	3.7	...	...
Sorghum fodder, dry	90.3	2.8	44.8	2.0	52.1	17.6	11.8	...	...
Sorghum fodder, high in water	62.6	1.5	32.9	1.8	38.4	24.6	6.2	...	...
Sorghum bagasse, dried	88.7	0.5	52.3	0.6	54.2	107.4	5.4	...	...
Durra fodder *	89.9	1.0	43.6	1.8	48.6	47.6	10.2	...	...
Broom-corn fodder *	90.6	0.6	44.6	1.1	47.7	78.5	6.2	...	...
Japanese cane fodder *	93.2	0.5	55.0	1.2	58.2	115.4	2.2	...	...
Sugar-cane bagasse *	89.8	0.5	47.6	3.3	55.5	110.0	5.3	...	...
Hay from the grasses, etc.									
Bent grass, Canada, or blue joint *	93.3	4.6	44.6	1.3	52.1	10.3	12.2	...	...
Bermuda grass	90.3	3.7	37.9	0.8	43.4	10.7	11.4	4.0	20.0
Black grass	89.7	4.4	39.4	1.1	46.3	9.5	12.0	2.0	18.8
Bluegrass, Canada	89.3	2.8	48.5	0.9	53.3	18.0	10.6	4.5	23.3
Bluegrass, Kentucky, all analyses	86.8	4.7	43.5	1.5	51.6	10.0	13.3	5.4	21.0
Bluegrass, Kentucky, in milk	87.6	4.8	44.1	1.5	52.3	9.9	13.6	...	...
Bluegrass, Kentucky, ripe	76.3	3.5	38.3	1.6	45.4	12.0	9.8	...	...
Bluegrass, native western *	91.9	6.4	44.0	1.6	54.0	7.4	17.9	...	...
Brome grass, smooth	91.5	5.0	44.2	0.9	51.2	9.2	15.8	4.2	21.5
Bluestem grasses *	93.1	2.4	44.6	0.8	48.8	19.3	7.8	...	...
Buffalo grass	93.0	3.8	43.9	0.8	49.5	12.0	11.2	...	....
Bunch grasses, miscellaneous	93.0	1.2	37.9	0.7	40.7	32.9	9.6	...	....
Carpet grass *	92.1	3.1	44.6	1.0	49.9	15.1	11.2	...	....
Chess, or cheat	91.6	3.0	35.5	0.7	40.1	12.4	11.5	6.6	17.8
Crab grass	90.5	3.5	40.0	1.0	45.7	12.1	12.8	9.0	30.9
Crow-foot grass *	90.5	3.8	40.0	0.9	45.8	11.1	13.8	...	....
Fescue, meadow	88.3	3.5	45.2	1.1	51.2	13.6	10.9	4.6	17.2
Fescues, native *	95.1	4.6	48.9	1.1	56.0	11.2	14.2	...	....
Fowl meadow grass *	88.9	6.1	43.0	1.4	52.3	7.6	15.7	...	....
Foxtails, miscellaneous *	93.2	5.6	48.0	1.7	57.4	9.2	14.9	...	....
Gama grass *	88.2	3.4	40.5	0.8	45.7	12.4	10.7	....	....
Grama grasses *	93.4	3.2	41.9	0.7	46.7	13.6	10.2	...	....
Hair grasses, miscellaneous *	93.4	4.2	41.9	0.9	48.1	10.5	13.3	4.7	17.3
Johnson grass	89.9	2.9	45.0	1.0	50.1	16.3	10.6	4.2	11.3
Millet, barnyard	86.5	5.1	40.5	0.8	47.4	8.3	13.3	5.5	25.3
Millet, common, or Hungarian	85.7	5.0	46.0	1.8	55.0	10.0	13.3	3.6	21.5
Millet, German *	91.3	4.8	49.7	1.7	58.3	11.1	12.8	3.5	14.4
Millet, hog, or broom-corn *	90.7	5.3	49.5	1.6	58.4	10.0	14.1	4.4	21.1
Millet, pearl, or cat-tail	87.2	4.2	43.8	0.8	49.8	10.9	10.7	...	....

TABLE III. Digestible nutrients and fertilizing constituents—*con.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbo-hydrates	Fat	Total		Nitro-gen	Phos-phoric acid	Potash
DRIED ROUGHAGE — con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Hay from the grasses, etc.—con.									
Millet, wild, or Indian *	93.3	6.4	49.5	1.5	59.3	8.3	17.0	...	....
Mixed grasses	87.2	4.3	44.3	1.2	51.3	10.9	12.2	3.8	16.4
Mixed grasses, rowen	86.4	7.0	39.9	1.6	50.5	6.2	19.7	3.3	16.6
Natal grass *	90.2	3.7	37.9	0.8	43.4	10.7	11.8	...	....
Needle grasses *	94.7	3.9	43.9	0.8	49.6	11.7	12.5	...	....
Nerved manna grass *	93.8	4.0	41.4	0.8	47.2	10.8	12.8	...	....
Oat grass, tall, or meadow oat grass	88.2	3.4	38.4	1.2	44.5	12.1	12.8	3.1	16.4
Old witch grass *	92.9	6.5	41.1	1.0	49.8	6.7	17.0	...	....
Orchard grass	88.4	4.7	41.1	1.6	49.4	9.5	12.6	4.0	19.4
Para grass	90.2	2.3	38.7	0.4	41.9	17.2	7.4	...	....
Panic grasses *	92.1	4.7	46.1	1.2	53.5	10.4	13.3	2.6	6.3
Prairie hay, western	93.5	4.0	41.4	1.1	47.9	11.0	12.8	...	...
Quack grass	94.1	4.2	49.7	1.1	56.4	12.4	11.7	...	...
Rescue grass *	90.2	5.0	43.0	1.2	50.7	9.1	15.7	5.5	15.6
Red top, all analyses	90.2	4.6	45.9	1.2	53.2	10.6	11.8	4.4	18.8
Red top, in bloom	92.0	4.5	46.4	1.1	53.4	10.9	11.5	...	....
Reed bent grass *	94.1	6.1	44.4	1.3	53.4	7.8	16.3	...	....
Reed canary grass *	90.4	4.5	44.6	1.4	52.3	10.6	12.6	5.2	18.9
Reed grasses, miscellaneous western *	93.0	3.1	42.8	0.9	47.9	14.5	9.9	...	....
Reed meadow grass, or manna *	93.3	4.6	39.8	0.8	46.2	9.0	14.9	...	....
Rhode Island bent grass *	88.5	4.1	45.0	1.6	52.7	11.9	10.6	4.1	17.0
Rye grass, Italian *	88.6	3.9	40.7	1.0	46.8	11.0	13.0	...	....
Rye grass, perennial *	88.0	4.4	39.0	1.6	47.0	9.7	14.7	...	....
Rushes, western	94.3	7.5	48.5	0.9	58.0	6.7	16.3	...	....
Salt grasses, miscellaneous	94.7	3.6	40.0	0.7	45.2	11.6	13.0	...	....
Sedges, western	94.8	6.9	49.8	1.0	58.9	7.5	17.9	...	....
Sedges, eastern *	90.7	2.7	41.8	0.6	45.9	16.0	9.8	2.0	9.3
Spear grasses	94.5	4.7	50.7	0.9	57.4	11.2	12.2	...	....
Swamp grasses *	90.2	3.5	40.1	0.8	45.4	12.0	12.3	...	....
Sweet vernal grass *	90.7	7.1	39.9	2.3	52.2	6.4	19.8	5.9	18.5
Teosinte *	89.4	5.6	40.2	0.9	47.8	7.5	14.6	7.5	42.6
Timothy, all analyses	88.4	3.0	42.8	1.2	48.5	15.2	9.9	3.1	13.6
Timothy, before bloom	92.8	4.7	42.0	1.6	50.3	9.7	15.7	...	....
Timothy, early to full bloom	87.2	3.6	44.7	1.2	51.0	13.2	10.1	...	....
Timothy, late bloom to early seed	85.1	2.4	39.0	1.4	44.6	17.6	8.8	...	....
Timothy, nearly ripe	87.5	2.2	40.7	1.1	45.4	19.6	8.3	...	....
Timothy rowen *	84.9	8.2	35.8	2.1	48.7	4.9	23.0	...	....
Wheat grass, common *	92.7	4.0	44.0	0.8	49.8	11.4	10.4	...	....
Wheat grasses, miscellaneous	93.6	4.4	44.7	0.8	50.9	10.6	11.4	...	....
Wheat grass, western	94.1	4.2	50.5	0.9	56.7	12.5	12.3	...	....
Wild barley, or foxtail *	92.5	4.0	48.4	1.1	54.9	12.7	11.2	...	....
Wild oat *	92.1	3.8	42.8	1.4	49.8	12.1	12.8	...	....
Wild rye *	89.2	4.0	47.3	1.1	53.8	12.4	11.4	6.3	19.5
Hay from the smaller cereals									
Barley hay, common	92.6	4.6	48.2	0.9	54.8	10.9	11.2	...	....
Barley hay, bald	91.3	4.8	47.0	0.9	53.8	10.2	11.8	...	....
Emmer hay *	92.3	6.5	44.3	0.9	52.8	7.1	16.0	...	....
Oat hay	88.0	4.5	38.1	1.7	46.4	9.3	13.4	8.0	32.7
Rye hay, all analyses *	91.9	2.9	41.1	1.1	46.5	15.0	10.7	5.0	17.0

Table III. Digestible nutrients and fertilizing constituents—*con.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbo-hydrates	Fat	Total		Nitro-gen	Phos-phoric acid	Potash
DRIED ROUGHAGE—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Hay from the smaller cereals—con.									
Rye hay, heading out to in bloom*	91.8	6.4	46.0	1.1	54.9	7.6	15.7	...	....
Wheat hay *	91.9	4.0	48.5	0.8	54.3	12.6	9.9	...	....
Hay from the legumes									
Alfalfa, all analyses	91.4	10.6	39.0	0.9	51.6	3.9	23.8	5.4	22.3
Alfalfa, first cutting	91.5	9.3	39.0	0.6	49.7	4.3	22.2	5.4	22.3
Alfalfa, second cutting	92.7	11.2	40.2	0.7	53.0	3.7	23.5	5.4	22.6
Alfalfa, third cutting	91.1	10.2	37.1	0.8	49.1	3.8	23.4	5.3	22.2
Alfalfa, fourth cutting *	84.0	11.1	33.6	0.7	46.3	3.2	25.4	4.9	20.5
Alfalfa, before bloom *	93.8	15.4	35.5	1.6	54.5	2.5	35.2	...	....
Alfalfa, in bloom	92.5	10.5	38.5	0.7	50.6	3.8	24.0	...	....
Alfalfa, in seed *	89.6	8.5	39.2	1.0	49.9	4.9	19.5	...	....
Alfalfa, variegated, or sand lucerne *	84.8	10.1	35.2	0.8	47.1	3.7	22.7	...	....
Alfalfa meal *	91.2	10.2	38.7	0.8	50.7	4.0	22.9	5.4	22.3
Alfalfa leaves *	93.4	15.8	35.1	1.3	53.8	2.4	36.0	...	....
Alfalfa stems *	94.4	1.8	46.9	0.4	49.6	26.6	10.1	...	....
Bean, whole plant *	87.4	16.4	37.8	0.8	56.0	2.4	36.0	...	....
Beggarweed *	90.9	11.6	36.2	0.7	49.4	3.3	24.6	9.4	27.9
Clover, alsike, all analyses	87.7	7.9	36.9	1.1	47.3	5.0	20.5	7.0	17.4
Clover, alsike, in bloom	87.4	8.2	36.4	1.3	47.5	4.8	21.1	...	....
Clover, bur	93.0	15.6	42.8	0.2	58.8	2.8	30.7	...	....
Clover, crimson, or scarlet	89.4	9.7	36.8	1.0	48.7	4.0	22.6	6.1	22.4
Clover, Egyptian, or berseem *	92.5	8.5	40.9	1.4	52.6	5.2	23.0	6.3	24.7
Clover, mammoth red *	81.3	6.4	37.2	1.8	47.6	6.4	17.3	6.3	8.7
Clover, red, all analyses	87.1	7.6	39.3	1.8	50.9	5.7	20.5	3.9	16.3
Clover, red, before bloom *	89.6	11.6	38.1	1.9	54.0	3.7	29.9	7.4	22.1
Clover, red, in bloom	86.1	8.1	38.8	1.8	50.9	5.3	21.0	5.7	15.4
Clover, red, after bloom *	77.9	6.8	34.1	2.6	46.7	5.9	18.6	4.0	11.0
Clover, sweet, white	91.4	10.9	38.2	0.7	50.7	3.7	23.2	6.6	12.6
Clover, sweet, yellow *	91.3	10.0	35.9	0.5	47.0	3.7	21.4	...	....
Clover, white	91.9	11.8	43.3	1.5	58.5	4.0	25.9	5.2	20.0
Clover meal *	91.5	8.1	42.0	1.3	53.0	5.5	21.9	4.0	17.2
Clover rowen	85.2	10.7	33.1	2.2	48.8	3.6	26.4	...	....
Cowpea, all analyses	90.3	13.1	33.7	1.0	49.0	2.7	30.9	9.6	41.3
Cowpea, before bloom *	92.2	17.8	27.0	1.0	47.0	1.6	41.9	...	....
Cowpea, in bloom to early pod *	89.4	12.6	34.6	1.3	50.1	3.0	29.6	...	....
Cowpea, ripe *	90.0	6.9	42.1	1.0	51.2	6.4	16.2	...	....
Flat pea *	92.3	18.4	37.3	1.7	59.5	2.2	36.3	6.9	24.3
Kudzu vine *	92.9	11.4	39.8	1.2	53.9	3.7	26.7	...	....
Lespedeza, or Japan clover *	88.2	8.6	41.1	1.1	52.2	5.1	19.4	10.3	20.7
Lupines	92.2	11.8	44.3	1.9	60.4	4.1	25.3	...	....
Pea, field	88.9	12.2	40.1	1.9	56.6	3.6	24.2	6.7	12.4
Pea, field, without peas *	90.6	7.7	47.0	0.9	56.7	6.4	15.2	...	....
Peanut vine, with nuts	92.2	9.6	39.6	8.3	67.9	6.1	21.3	...	....
Peanut vine, without nuts	78.5	6.6	37.0	3.0	50.4	6.6	14.6	2.2	13.9
Sanfoin	84.1	7.4	39.8	1.7	51.0	5.9	16.8	4.6	13.1
Serradella	90.3	11.8	35.1	1.6	50.5	3.3	25.1	10.3	15.1
Soybean hay	91.4	11.7	39.2	1.2	53.6	3.6	25.6	6.8	23.3
Trefoil, yellow, or black medic *	88.8	12.0	37.5	1.1	52.0	3.3	27.0	5.7	8.1
Velvet bean *	92.8	12.0	40.3	1.4	55.5	3.6	26.2	5.5	26.5

TABLE III. Digestible nutrients and fertilizing constituents—*con.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbo-hydrates	Fat	Total		Nitro-gen	Phos-phoric acid	Potash
DRIED ROUGHAGE — con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Hay from the legumes— con.									
Vetch, common	92.9	11.6	42.8	1.6	58.0	4.0	27.7	7.9	18.6
Vetch, hairy	87.7	15.7	37.1	1.9	57.1	2.6	31.8	10.3	26.2
Vetch, kidney *	90.3	8.1	43.1	1.0	53.4	5.6	19.4	8.9	13.4
Vetches, wild *	93.4	11.4	43.5	1.5	58.3	4.1	27.2	...	....
Hay from mixed legumes and grasses									
Clover and mixed grasses	89.9	4.7	39.9	1.3	47.5	9.1	15.8	4.1	20.0
Clover and timothy	87.8	4.0	39.7	1.1	46.2	10.6	13.8	4.7	19.0
Clover mixed rowen *	87.0	7.7	37.4	1.7	48.9	5.4	18.9	...	....
Cowpeas and millet *	90.3	9.3	34.7	0.9	46.0	3.9	21.9	...	....
Peas and oats	83.4	8.3	37.1	1.5	48.8	4.9	18.2	6.6	16.4
Peas, oats, and barley *	83.5	9.2	36.9	1.8	50.1	4.4	20.2	...	....
Vetch and oats	84.3	6.9	37.0	1.4	47.1	5.8	17.0	6.0	12.7
Vetch and wheat	85.0	10.7	41.1	1.3	54.7	4.1	23.2	...	....
Straw and chaff from the cereals									
Barley straw	85.8	0.9	40.2	0.6	42.5	46.2	5.6	1.8	12.0
Buckwheat straw *	90.1	4.2	26.3	1.2	33.2	6.9	8.3	1.3	11.3
Flax shives	92.8	5.8	25.2	3.0	37.8	5.5	11.5	1.9	10.5
Millet straw *	85.8	1.0	41.7	0.6	44.1	43.1	5.8	1.8	17.3
Oat straw	88.5	1.0	42.6	0.9	45.6	44.6	5.8	2.1	15.0
Oat chaff	91.8	2.2	34.3	1.2	39.2	16.8	9.4	1.3	4.5
Rice straw	92.5	0.9	37.8	0.3	39.4	42.8	6.2	1.4	15.4
Rye straw	92.9	0.7	39.6	0.4	41.2	57.9	4.8	2.8	7.9
Wheat straw	91.6	0.7	35.1	0.5	36.9	51.7	5.0	1.3	7.4
Wheat straw from rusted grain *	91.9	2.0	33.3	0.4	36.2	17.1	13.9	...	..
Wheat chaff	85.6	1.1	25.7	0.6	28.2	24.6	6.7	4.0	8.4
Legume straws									
Bean *	89.5	3.6	42.4	0.7	47.6	12.2	11.7	4.2	13.6
Crimson clover *	87.7	3.8	36.5	0.9	42.3	10.1	12.0	...	....
Cowpea *	91.5	3.4	39.1	0.7	44.1	12.0	10.9	...	....
Horse bean	87.9	4.2	38.2	0.8	44.2	9.5	13.8	3.0	20.3
Soybean	88.1	2.8	38.5	1.0	43.5	14.5	9.0	1.2	8.9
Miscellaneous dry roughages									
Alfilaria *	88.9	6.3	39.7	1.7	49.8	6.9	17.8	...	...
Artichoke tops *	74.2	2.7	50.8	0.3	54.2	19.1	6.7	2.9	10.5
Brush feed *	95.0	1.2	37.3	0.7	40.1	32.4	8.6	...	....
Burnet *	88.9	7.4	39.2	2.0	51.1	5.9	20.8	10.3	47.7
Daisy, field *	90.7	8.0	38.5	2.2	51.5	5.4	22.6	4.2	26.1
Furze *	94.5	2.7	32.3	0.6	36.4	12.5	18.6	6.5	24.4
Greasewood *	95.4	14.8	22.6	1.0	39.6	1.7	31.7	5.4	28.9
Prickly comfrey *	92.1	22.7	37.7	1.5	63.8	1.8	40.8	...	....
Purslane *	88.1	19.8	34.9	2.1	59.4	2.0	35.7	8.6	96.7
Rape *	88.7	16.8	47.2	1.6	67.6	3.0	30.2	12.6	46.8
Russian thistle *	94.2	5.1	31.4	1.2	39.2	6.7	29.1	....	....
Saltbushes*	93.4	10.1	24.7	0.6	36.2	2.6	21.6	13.6	56.5
Spurrey *	92.1	7.9	41.5	3.0	56.2	6.1	18.1	....	....
Sweet potato vines *	88.7	6.0	37.1	1.6	46.7	6.8	20.0	5.4	16.4

TABLE III. Digestible nutrients and fertilizing constituents—*con.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
FRESH GREEN ROUGHAGE	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Corn, the sorghums, etc.									
Corn fodder, all analyses *	21.9	1.0	12.8	0.4	14.7	13.7	3.0	1.1	3.7
Dent corn fodder, all analyses	23.1	1.0	13.7	0.4	15.6	14.6	3.0	1.1	4.5
Dent corn fodder, in tassel	14.9	1.1	8.2	0.3	10.0	8.1	2.6	...	...
Dent corn fodder, in milk	19.9	1.0	12.1	0.5	14.2	13.2	2.6	...	...
Dent corn fodder, dough to glazing *	25.1	1.3	15.4	0.7	18.3	13.1	3.4	...	...
Dent corn fodder, kernels glazed	26.2	1.1	15.8	0.4	17.8	15.2	3.2	...	...
Dent corn fodder, kernels ripe	34.8	1.5	21.1	0.8	24.4	15.3	4.3	...	...
Flint corn fodder, all analyses	20.7	1.0	12.4	0.4	14.3	13.3	3.0	1.0	4.0
Flint corn fodder, in tassel *	10.6	0.9	5.5	0.3	7.1	6.9	2.2	...	...
Flint corn fodder, in milk *	15.0	0.9	8.9	0.4	10.7	10.9	2.4	...	...
Flint corn fodder, kernels glazed	21.0	1.0	12.3	0.6	14.7	13.7	3.0	...	...
Flint corn fodder, kernels ripe	27.9	1.2	16.6	0.7	19.4	15.2	3.8	...	...
Sweet corn fodder, before milk stage *	10.0	0.8	6.1	0.2	7.3	8.1	1.6	0.5	1.9
Sweet corn fodder, roasting ears or later	20.3	1.2	12.0	0.4	14.1	10.8	3.0	0.9	3.8
Sweet corn fodder, ears removed *	21.5	1.0	13.1	0.3	14.8	13.8	2.6	...	...
Sweet corn ears, including husks *	37.8	3.0	24.4	1.9	31.7	9.6	6.1	4.0	4.8
Corn fodder, pop *	16.9	0.8	9.9	0.3	11.4	13.2	2.1	...	...
Corn stover, green (ears removed)*	22.7	0.5	12.0	0.2	12.9	24.8	2.1	1.1	3.4
Corn leaves and tops *	15.9	1.3	8.4	0.5	10.8	7.3	3.0	...	...
Corn leaves *	31.1	2.1	16.5	0.6	20.0	8.5	5.1	1.0	7.1
Corn husks *	36.5	1.0	22.7	0.3	24.4	23.4	2.9	0.6	5.5
Kafir fodder, all analyses *	23.6	1.1	12.4	0.4	14.4	12.1	3.8	1.6	5.1
Kafir fodder, heads just showing *	19.9	0.8	11.6	0.3	13.1	15.4	2.6	...	...
Milo fodder *	22.7	0.8	12.7	0.3	14.2	16.8	2.9	1.7	7.5
Sweet sorghum fodder	24.9	0.7	14.1	0.6	16.2	22.1	2.4	1.1	4.1
Durra fodder *	22.4	0.9	12.0	0.4	13.8	14.3	3.2	1.8	5.6
Broom-corn fodder *	22.9	0.9	12.1	0.3	13.7	14.2	3.2	1.7	7.0
Sugar cane *	21.7	0.4	12.3	0.6	14.1	34.2	1.4	...	...
Fresh green grass									
Bent grass, Canada, or bluejoint *	44.6	2.0	21.7	0.6	25.1	11.6	6.6	...	...
Bermuda grass *	33.2	1.4	17.0	0.5	19.5	12.9	4.8	1.5	7.4
Bluegrass, Canada *	33.2	1.3	17.2	0.4	19.4	13.9	4.8	1.8	6.9
Bluegrass, Kentucky, all analyses *	31.6	2.3	14.8	0.6	18.5	7.0	6.6	1.9	7.1
Bluegrass, Kentucky, before heading *	23.8	3.7	10.4	0.8	15.9	3.3	8.5	...	...
Bluegrass, Kentucky, headed out *	36.4	2.8	16.7	0.7	21.1	6.5	7.8	...	...
Bluegrass, Kentucky, after bloom *	43.6	1.9	21.9	0.7	25.4	12.4	5.4	...	...
Bluegrasses, native	45.3	2.0	20.7	0.6	24.1	11.0	5.1	...	...
Brome grass, smooth *	33.0	2.9	15.0	0.2	18.3	5.3	6.7	2.0	8.6
Brome grasses, miscellaneous	36.3	3.1	16.8	0.2	20.3	5.5	7.2	2.2	9.5
Bluejoint grasses, western *	38.9	1.7	17.6	0.4	20.2	10.9	4.2	...	...
Bluestem grasses *	31.6	1.9	13.2	0.8	16.9	7.9	4.8	...	...

TABLE III. Digestible nutrients and fertilizing constituents—*con.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
FRESH GREEN ROUGHAGE—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Fresh green grass—con.									
Bunch grasses *	49.4	2.8	21.4	0.6	25.6	8.1	6.9	...	...
Chess or cheat *	39.6	1.5	20.8	0.6	23.7	14.8	5.1	2.9	7.7
Crab grass *	30.9	1.3	14.2	0.5	16.6	11.8	4.3	2.2	10.8
Fescue, meadow *	30.5	1.6	15.0	0.5	17.7	10.1	4.8	1.8	7.0
Fescues, native *	36.0	1.8	18.2	0.4	20.9	10.6	5.6	...	...
Guinea grass *	28.5	1.1	14.1	0.4	16.1	13.6	3.5	...	...
Grama grass *	36.1	2.1	15.7	0.4	18.7	7.9	5.3	...	...
Johnson grass *	29.1	1.2	14.7	0.5	17.0	13.2	4.0	...	...
Meadow foxtail *	29.6	2.1	13.9	0.6	17.4	7.3	5.8	...	...
Millet, barnyard	21.3	1.0	12.1	0.4	14.0	13.0	2.7	1.4	6.2
Millet, common, or Hungarian	27.6	1.9	14.8	0.6	18.1	8.5	4.6	1.2	6.9
Millet, hog, or broom-corn *	24.7	1.3	13.8	0.4	16.0	11.3	3.2	1.2	5.7
Millet, pearl, or cat-tail *	18.7	1.1	10.4	0.2	11.9	9.8	2.9	1.9	10.3
Mixed grasses, immature	29.7	3.6	14.5	0.9	20.1	4.6	8.2	2.1	7.9
Mixed grasses, at haying stage	30.8	1.7	15.2	0.6	18.3	9.8	4.8	2.5	6.4
Oat grass, tall, or meadow oat grass *	30.3	1.1	13.3	0.4	15.3	12.9	4.2	1.8	8.4
Orchard grass	29.2	1.7	13.0	0.6	16.1	8.5	4.6	2.1	9.5
Para grass *	27.2	0.8	14.0	0.3	15.5	18.4	2.7	...	...
Quack grass *	25.0	2.2	11.3	0.7	15.1	5.9	6.1	...	...
Rescue grass *	30.6	2.6	14.5	0.2	17.5	5.7	6.1	1.9	5.3
Red top	39.3	1.9	20.0	0.6	23.3	11.3	5.0	2.3	8.4
Reed canary grass *	37.0	1.7	18.3	0.6	21.4	11.6	5.8	2.3	9.8
Reed meadow grass *	30.7	1.3	15.4	0.3	17.4	12.4	4.5	...	...
Rhode Island bent grass *	32.7	1.4	16.4	0.4	18.7	12.4	4.6	2.2	8.6
Rowen, mixed	28.2	3.3	14.0	0.9	19.3	4.8	7.5	2.0	7.5
Rye grass, Italian *	27.1	1.8	12.7	0.7	16.1	7.9	5.0	2.0	7.5
Rye grass, perennial *	26.6	1.7	12.5	0.7	15.8	8.3	4.8	2.2	9.2
Rushes, western *	31.1	2.5	16.2	0.3	19.4	6.8	5.4	...	...
Sedges, western *	38.5	2.4	20.3	0.5	23.8	8.9	6.1	...	...
Spear grasses, miscellaneous *	43.6	2.0	23.6	0.4	26.5	12.2	5.3	1.6	8.0
Sweet vernal grass *	31.2	1.5	16.1	0.5	18.7	11.5	4.2	2.0	6.4
Teosinte *	21.3	1.0	11.9	0.3	13.6	12.6	2.7	2.0	9.3
Timothy, all analyses	37.5	1.5	19.3	0.6	22.2	13.8	5.0	1.8	6.7
Timothy, before bloom *	24.2	1.8	13.8	0.4	16.5	8.2	4.0	...	...
Timothy, in bloom	32.1	1.3	16.4	0.5	18.8	13.5	4.3	...	...
Timothy, in seed	46.4	1.5	24.7	0.7	27.8	17.5	5.0	...	...
Timothy, mountain *	37.5	1.4	19.6	0.5	22.1	14.8	4.8	...	...
Wheat grasses, miscellaneous *	45.3	2.2	24.1	0.5	27.4	11.5	6.4	...	...
Wild barley *	35.7	2.4	15.9	0.7	19.9	7.3	7.8	...	...
Wild oats *	36.6	1.5	18.7	0.7	21.8	13.5	4.2	...	...
Wild rye *	23.3	2.1	10.4	0.5	13.6	5.5	5.9	...	...
Green fodder from the smaller cereals									
Barley fodder	23.2	2.3	11.5	0.4	14.7	5.4	5.3	1.3	6.8
Buckwheat, Japanese *	36.6	2.2	17.4	0.5	20.7	8.4	7.4	2.0	9.3
Oat fodder	26.1	2.3	11.8	0.8	15.9	5.9	5.1	1.8	7.7
Oat fodder, 8 in. high *	13.0	3.4	4.1	0.5	8.6	1.5	7.8	...	...
Rye fodder	21.3	2.1	12.2	0.5	15.4	6.3	4.2	1.5	4.9
Rye fodder, 5 in. high	18.1	5.1	6.2	0.7	12.9	1.5	10.4	...	...
Wheat fodder, all analyses *	27.4	2.8	15.1	0.6	19.3	5.9	5.8	1.9	7.2
Wheat fodder, 5 in. high *	24.2	5.1	10.3	0.5	16.5	2.2	10.4	...	...

TABLE III. Digestible nutrients and fertilizing constituents—*con.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbo-hydrates	Fat	Total		Nitro-gen	Phos-phoric acid	Potash
FRESH GREEN ROUGHAGE—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Green legumes									
Alfalfa, all analyses	25.3	3.3	10.4	0.4	14.6	3.4	7.2	1.5	6.7
Alfalfa, before bloom *	19.9	3.5	7.5	0.3	11.7	2.3	7.5	...	...
Alfalfa, in bloom *	25.9	3.3	10.8	0.3	14.8	3.5	7.0	...	...
Alfalfa, after bloom *	29.8	2.1	13.5	0.2	16.0	6.6	4.6	1.7	7.9
Beggarweed *	27.1	3.1	11.6	0.2	15.1	3.9	6.7	2.7	5.7
Clover, alsike *	24.3	2.7	11.8	0.4	15.4	4.7	6.6	1.8	9.2
Clover, alsike, in bloom *	21.5	2.3	10.4	0.4	13.6	4.9	5.6	...	...
Clover, bur *	20.8	3.4	8.2	1.1	14.1	3.1	8.2	...	...
Clover, crimson	17.4	2.3	8.1	0.4	11.3	3.9	4.8	2.0	4.1
Clover, mammoth red *	25.1	2.7	12.4	0.3	15.8	4.9	6.4	...	...
Clover, red, all analyses	26.2	2.7	13.0	0.6	17.1	5.3	6.6	1.3	5.6
Clover, red, in bloom *	27.5	2.7	13.8	0.7	18.1	5.7	6.6	...	...
Clover, red, rowen	34.4	3.3	15.4	0.8	20.5	5.2	8.5	2.0	9.5
Clover, sweet *	24.4	3.3	10.3	0.3	14.3	3.3	7.0	1.3	5.0
Clover, white *	21.8	3.1	9.6	0.5	13.8	3.5	7.4	1.8	8.1
Cowpeas	16.3	2.3	8.0	0.3	11.0	3.8	4.8	1.4	6.2
Flat pea *	22.5	4.6	9.1	0.4	14.6	2.2	9.1	1.5	4.6
Jack bean *	23.2	4.0	9.2	0.3	13.9	2.5	8.3	...	...
Horse bean *	17.6	2.8	7.4	0.3	10.9	2.9	5.8	1.2	3.7
Kudzu vine *	30.6	4.2	13.9	0.5	19.2	3.6	8.8	...	...
Lespedeza or Japan clover *	36.6	4.5	17.1	0.6	23.0	4.1	10.7	...	...
Lupines	17.4	2.6	8.0	0.3	11.3	3.3	5.4	0.9	5.1
Peas, field, Canada	16.6	2.9	7.1	0.3	10.7	2.7	5.8	1.1	2.8
Peas, field, miscellaneous *	18.8	2.6	8.6	0.3	11.9	3.6	5.1	1.2	3.2
Sanfoin	25.6	2.8	12.3	0.5	16.2	4.8	6.1	1.4	4.0
Serradella *	20.2	2.1	8.9	0.5	12.1	4.8	4.6	1.3	4.1
Soybeans, all analyses	23.6	3.2	10.2	0.5	14.5	3.5	6.6	1.8	5.7
Soybeans, in bloom *	20.8	3.0	8.5	0.3	12.2	3.1	6.2	...	...
Soybeans, in seed *	24.2	3.1	10.7	0.5	14.9	3.8	6.4	...	...
Trefoil, yellow, or black medic *	22.7	3.3	9.2	0.3	13.2	3.0	7.2	...	...
Velvet bean *	17.9	2.7	7.2	0.4	10.8	3.0	5.6	1.3	4.5
Vetch, common	20.4	2.7	8.9	0.3	12.3	3.6	6.1	1.6	5.0
Vetch, kidney *	27.7	2.6	12.8	0.3	16.1	5.2	5.9	...	...
Vetch, hairy	18.1	3.5	8.1	0.4	12.5	2.6	6.7	1.4	5.1
Vetches, wild *	24.6	4.2	12.1	0.4	17.2	3.1	8.2	1.7	6.0
Mixed legumes and grasses									
Clover and mixed grasses *	27.3	2.2	14.1	0.6	17.7	7.0	4.8	...	...
Cowpeas and corn *	20.0	1.3	11.4	0.3	13.4	9.3	3.4	...	...
Cowpeas and oats *	21.8	3.3	9.1	0.6	13.8	3.2	7.2	...	...
Cowpeas and sorghum *	18.7	0.7	10.0	0.3	11.4	15.3	2.4	...	...
Peas and millet *	19.7	1.9	8.4	0.8	12.1	5.4	4.2	...	...
Peas and barley	20.2	2.7	8.8	0.5	12.6	3.7	5.8	1.6	5.9
Peas and oats	22.6	2.4	10.6	0.6	14.4	5.0	5.1	1.7	6.1
Peas, oats, and rape *	17.9	2.3	7.3	0.5	10.7	3.7	5.0	1.0	4.4
Soybeans and corn *	23.8	1.7	13.6	0.6	16.7	8.8	4.3	1.1	4.0
Soybeans and kafir *	17.1	0.9	7.9	0.4	9.7	9.8	3.2	...	...
Vetch and barley *	20.0	2.1	10.5	0.2	13.0	5.2	4.5	...	...
Vetch and oats	26.5	2.8	13.3	0.4	17.0	5.1	6.1	1.6	6.3
Vetch and wheat	22.7	2.4	12.2	0.3	15.3	5.4	5.3	...	...

TABLE III. Digestible nutrients and fertilizing constituents—*con.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
FRESH GREEN ROUGHAGE—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Roots and tubers									
Artichokes *	20.5	1.0	14.6	0.1	15.8	14.8	3.2	1.4	4.9
Beet, common *	13.0	0.9	9.1	0.1	10.2	10.3	2.6	1.0	8.5
Beet, sugar	16.4	1.2	12.6	0.1	14.0	10.7	2.6	0.8	3.2
Carrot	11.7	0.9	8.6	0.2	9.9	10.0	1.9	1.1	2.7
Cassava *	32.6	0.6	26.4	0.2	27.4	44.7	1.8	1.0	4.0
Chufa *	20.5	0.4	10.2	3.3	18.0	44.0	1.1	...	...
Mangel	9.4	0.8	6.4	0.1	7.4	8.2	2.2	0.4	2.2
Onion *	12.4	0.8	9.6	0.2	10.8	12.5	2.1	0.9	2.2
Parsnip *	16.6	1.3	12.5	0.4	14.7	10.3	2.7	1.3	4.9
Potato	21.2	1.1	15.8	0.1	17.1	14.5	3.5	1.2	5.3
Rutabaga	10.9	1.0	7.7	0.3	9.4	8.4	1.9	1.2	5.0
Sweet potato *	31.2	0.9	24.2	0.3	25.8	27.7	2.9	0.9	5.1
Turnip	9.5	1.0	6.0	0.2	7.4	6.4	2.2	1.3	2.9
Miscellaneous green forages									
Alfilaria *	16.3	2.2	7.0	0.2	9.6	3.4	5.1	...	...
Apple *	18.2	0.4	15.6	0.2	16.4	40.0	0.8	0.3	1.6
Apple pomace *	23.3	1.2	15.6	0.8	18.6	14.5	2.6	0.6	1.5
Burnet *	19.9	2.7	12.8	0.3	16.2	5.0	4.8	2.1	8.8
Cabbage	8.9	1.9	5.6	0.2	7.9	3.2	3.5	0.7	2.9
Cabbage waste, outer leaves	14.1	1.7	6.5	0.1	8.4	3.9	4.3	...	...
Cactus, cane, entire plant *	10.4	0.4	5.8	0.1	6.4	15.0	1.4	0.3	2.1
Cactus, cane, fruit *	18.6	0.8	9.9	0.5	11.8	13.8	2.4	...	...
Cactus, cane, stems *	21.7	0.8	11.8	0.3	13.3	15.6	2.4	0.8	4.8
Cactus, prickly pear	16.5	0.4	8.9	0.2	9.7	23.2	1.3	0.7	4.3
Cactus, prickly pear, old joints *	16.4	0.3	9.1	0.2	9.8	31.7	1.0	0.6	4.0
Cactus, prickly pear, young joints *	12.9	0.4	6.9	0.3	8.0	19.0	1.4	0.5	3.3
Kale	11.3	1.9	4.7	0.3	7.3	2.8	3.8	...	...
Kohlrabi *	9.0	1.7	5.6	0.1	7.5	3.4	3.2	...	...
Melon, pie, or stock *	6.1	0.5	3.9	0.2	4.8	8.6	1.1	...	...
Mustard, white *	14.0	3.6	6.5	0.3	10.8	2.0	6.6	...	...
Potato pomace, wet *	8.3	0.4	6.0	0.1	6.6	15.4	1.1	1.3	3.0
Prickly comfrey *	12.8	2.2	7.0	0.1	9.4	3.3	4.0	1.8	9.5
Pumpkin, field	8.3	1.1	4.5	0.5	6.7	5.1	2.2	0.9	3.2
Purslane *	10.3	2.0	5.4	0.1	7.6	2.8	3.5	1.0	11.3
Rape	16.7	2.6	10.0	0.3	13.3	4.1	4.6	1.1	3.9
Russian thistle *	20.4	2.2	7.6	0.2	10.2	3.6	4.8	...	...
Saltbush, Australian *	23.3	2.8	5.9	0.2	9.1	2.2	5.9	3.4	14.1
Saltbushes, miscellaneous *	24.3	2.9	6.6	0.1	9.7	2.3	6.2	...	...
Sugar beet leaves *	11.6	1.2	6.3	0.1	7.7	5.4	3.0	1.2	5.5
Sugar beet tops *	11.4	1.7	5.4	0.1	7.3	3.3	4.2	1.0	6.4
Sunflower, whole plant *	23.7	2.2	10.7	1.3	15.8	6.2	5.8	...	...
Turnip tops *	15.0	1.8	7.3	0.1	9.3	4.2	4.5	1.5	5.2
SILAGE									
Silage from corn, the sorghums, etc.									
Corn, well matured, recent analyses	26.3	1.1	15.0	0.7	17.7	15.1	3.4	1.6	4.4
Corn, immature	21.0	1.0	11.4	0.4	13.3	12.3	3.0	1.2	3.5
Corn, early analyses	23.1	1.0	12.6	0.6	15.0	14.0	3.0	1.4	3.9
Corn, from frosted corn *	25.3	1.2	13.7	0.6	16.3	12.6	3.5	1.5	4.3
Corn, from field-cured stover *	19.6	0.5	9.9	0.4	11.3	21.6	2.2	...	...

TABLE III. Digestible nutrients and fertilizing constituents—*con.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbo-hydrates	Fat	Total		Nitro-gen	Phos-phoric acid	Potash
SILAGE—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Silage from corn, the sorghums, etc.—con.									
Durra *	20.3	0.6	9.9	0.4	11.4	18.0	1.9	...	...
Kafir	30.8	0.8	15.3	0.6	17.5	20.9	2.9	...	...
Sorghum	22.8	0.6	11.6	0.5	13.3	21.2	2.4	1.5	1.9
Japanese cane *	22.4	0.6	11.2	0.3	12.5	19.8	2.4	...	...
Sugar-cane tops *	23.5	0.5	12.2	0.2	13.1	25.2	1.9	...	...
Miscellaneous silage									
Alfalfa *	24.6	1.2	7.8	0.6	10.4	7.7	5.6	...	...
Apple pomace *	20.6	0.9	15.0	0.6	17.3	18.2	2.6	0.8	2.2
Barley *	25.0	2.0	12.0	0.8	15.8	6.9	4.2	...	...
Clover	27.8	1.3	9.5	0.5	11.9	8.2	5.9	...	...
Corn and clover *	28.6	2.1	15.9	0.7	19.6	8.3	5.3	...	...
Corn and rye *	19.4	1.1	10.0	1.0	13.3	11.1	3.4	...	...
Corn and soybean	24.7	1.6	13.8	0.8	17.2	9.8	4.0	1.6	4.5
Cowpea	22.0	1.8	10.1	0.6	13.3	6.4	5.1	1.8	3.8
Cowpea and soybean *	28.5	1.9	13.2	0.7	16.7	7.8	5.4	1.7	5.6
Field pea *	27.9	2.8	13.1	0.9	17.9	5.4	6.1	2.9	2.3
Millet *	31.6	1.6	15.3	0.8	18.7	10.7	4.5	...	...
Millet, barnyard, and soybean	21.0	1.6	9.2	0.7	12.4	6.8	4.5	...	...
Mixed grasses *	30.7	1.3	15.0	0.6	17.7	12.6	3.7	...	...
Oat *	28.3	1.5	13.8	0.9	17.3	10.5	3.2	...	...
Oat and pea	27.5	2.8	12.6	1.0	17.6	5.3	6.1	1.7	7.0
Pea-cannery refuse *	23.2	1.6	11.6	0.8	15.0	8.4	4.5	...	...
Rye *	27.2	2.4	16.1	0.5	19.6	7.2	4.8	1.7	6.9
Sorghum and cowpea *	32.3	0.9	16.6	0.6	18.9	20.0	3.8	...	...
Soybean	27.1	2.6	11.0	0.7	15.2	4.8	6.2	1.7	7.1
Sugar beet leaves *	23.0	2.1	10.0	0.4	13.0	5.2	4.5	...	...
Sugar beet pulp *	10.0	0.8	6.5	0.3	8.0	9.0	2.4	...	...
Vetch	30.1	2.0	15.2	0.8	19.0	8.5	5.6	...	...
Wet brewers' grains *	29.8	5.2	11.1	1.9	20.6	3.0	10.2	...	...

Table IV. Wolff-Lehmann Feeding Standards for Farm Animals

The Wolff-Lehmann Feeding Standards have been fully discussed in a preceding chapter. (**156-7, 168, 187-8**) It is there pointed out that we now have more accurate data on the nutrient requirements of various classes of animals than was possessed by scientists when these standards were formulated. For students and stockmen who desire to compute rations substantially in accordance with the Wolff-Lehmann system, but taking into consideration the results of recent feeding trials at the Experiment Stations, the authors have drawn up the "Modified Wolff-Lehmann Feeding Standards" given in Appendix Table V. The Wolff-Lehmann Standards, as last presented by Lehmann in the Mentzel and Lengerke Agricultural Calendar for 1906, are here given, however, because historically this table is worthy of a place in any book on the feeding of farm animals, and further because no matter what line one may ultimately follow in these matters, he should know and understand the teachings of Wolff and Lehmann.

The standards for milch cows are given for the middle of the lactation period with animals yielding milk of average composition. The standards for growing animals contemplate only a moderate amount of exercise; if much is taken, add 15 per cent—mostly non-nitrogenous nutrients—to the ration. If no exercise is taken, deduct 15 per cent from the standard. The standards are for animals of normal size. Those of small breeds will require somewhat more nutrients, amounting in some cases to 0.3 of a pound of nitrogenous and 1.5 pounds of non-nitrogenous digestible nutrients daily for 1,000 pounds of live weight of animals.

Animal	Per day per 1,000 lbs. live weight				
		Digestible nutrients			
	Dry matter	Crude protein	Carbo-hy-drates	Fat	Nutri-tive ratio
	Lbs.	Lbs.	Lbs.	Lbs.	1:
1. *Oxen*					
At rest in stall	18	0.7	8.0	0.1	11.8
At light work	22	1.4	10.0	0.3	7.7
At medium work	25	2.0	11.5	0.5	6.5
At heavy work	28	2.8	13.0	0.8	5.3
2. *Fattening cattle*					
First period	30	2.5	15.0	0.5	6.5
Second period	30	3.0	14.5	0.7	5.4
Third period	26	2.7	15.0	0.7	6.2
3. *Milch cows, yielding daily*					
11.0 pounds of milk	25	1.6	10.0	0.3	6.7
16.6 pounds of milk	27	2.0	11.0	0.4	6.0
22.0 pounds of milk	29	2.5	13.0	0.5	5.7
27.5 pounds of milk	32	3.3	13.0	0.8	4.5
4. *Sheep*					
Coarse wool	20	1.2	10.5	0.2	9.1
Fine wool	23	1.5	12.0	0.3	8.5

TABLE IV. Wolff-Lehmann feeding standards for farm animals — *continued.*

Animal	Per day per 1,000 lbs. live weight				
		Digestible nutrients			
	Dry matter	Crude protein	Carbo-hy-drates	Fat	Nutri-tive ratio
5. *Breeding ewes*	Lbs.	Lbs.	Lbs.	Lbs.	1:
With lambs	25	2.9	15.0	0.5	5.6
6. *Fattening sheep*					
First period	30	3.0	15.0	0.5	5.4
Second period	28	3.5	14.5	0.6	4.5
7. *Horses*					
Light work	20	1.5	9.5	0.4	7.0
Medium work	24	2.0	11.0	0.6	6.2
Heavy work	26	2.5	13.3	0.8	6.0
8. *Brood sows*	22	2.5	15.5	0.4	6.6
9. *Fattening swine*					
First period	36	4.5	25.0	0.7	5.9
Second period	32	4.0	24.0	0.5	6.3
Third period	25	2.7	18.0	0.4	7.0
10. *Growing cattle, dairy breeds*					
Age in months — Av. live wt. per head, lbs.					
2– 3 — 150	23	4.0	13.0	2.0	4.5
3– 6 — 300	24	3.0	12.8	1.0	5.1
6–12 — 500	27	2.0	12.5	0.5	6.8
12–18 — 700	26	1.8	12.5	0.4	7.5
18–24 — 900	26	1.5	12.0	0.3	8.5
11. *Growing cattle, beef breeds*					
2– 3 — 160	23	4.2	13.0	2.0	4.2
3– 6 — 330	24	3.5	12.8	1.5	4.7
6–12 — 550	25	2.5	13.2	0.7	6.0
12–18 — 750	24	2.0	12.5	0.5	6.8
18–24 — 950	24	1.8	12.0	0.4	7.2
12. *Growing sheep, wool breeds*					
4– 6 — 60	25	3.4	15.4	0.7	5.0
6– 8 — 75	25	2.8	13.8	0.6	5.4
8–11 — 80	23	2.1	11.5	0.5	6.0
11–15 — 90	22	1.8	11.2	0.4	7.0
15–20 — 100	22	1.5	10.8	0.3	7.7
13. *Growing sheep, mutton breeds*					
4– 6 — 60	26	4.4	15.5	0.9	4.0
6– 8 — 80	26	3.5	15.0	0.7	4.8
8–11 — 100	24	3.0	14.3	0.5	5.2
11–15 — 120	23	2.2	12.6	0.5	6.3
15–20 — 150	22	2.0	12.0	0.4	6.5
14. *Growing swine, breeding stock*					
2– 3 — 50	44	7.6	28.0	1.0	4.0
3– 5 — 100	35	4.8	22.5	0.7	5.0
5– 6 — 120	32	3.7	21.3	0.4	6.0
6– 8 — 200	28	2.8	18.7	0.3	7.0
8–12 — 250	25	2.1	15.3	0.2	7.5
15. *Growing, fattening swine*					
2– 3 — 50	44	7.6	28.0	1.0	4.0
3– 5 — 100	35	5.0	23.1	0.8	5.0
5– 6 — 150	33	4.3	22.3	0.6	5.5
6– 8 — 200	30	3.6	20.5	0.4	6.0
9–12 — 300	26	3.0	18.3	0.3	6.4

Table V. Modified Wolff-Lehmann Feeding Standards for Farm Animals

It has been pointed out on previous pages that the recent investigations of the experiment stations of this and other countries have shown that the original Wolff-Lehmann standards are in many instances inaccurate. (**187-90**) To provide a means by which rations can be computed substantially in accordance with the Wolff-Lehmann system, while taking into consideration the results of the recent scientific work on live stock feeding, the following standards are presented. The recommendations for dairy cows are based on the standards of Haecker and Savage. (**182, 184, 186**) The standards for growing, fattening steers are hitherto unpublished recommendations by Haecker, based upon his extensive investigations at the Minnesota Station. (**123**) In the recommendations for fattening lambs the Bull-Emmett standards have been chiefly used. (**175**) The standards for the other classes of farm animals are based upon studies by the authors, of feeding trials at the various experiment stations, and upon the standards of Kellner, Armsby, and Pott. The method of computing rations in accordance with these standards has been fully explained in the text. (**190, 193-5**)

In most instances a minimum and a maximum are indicated for dry matter, digestible crude protein, and total digestible nutrients. As has been pointed out in the text (**146**), when protein-rich feeds are cheaper than carbonaceous feeds, somewhat more digestible crude protein may be supplied than is stated in the standards. This will narrow the nutritive ratio beyond the limits here indicated. On the other hand, the amount of protein should not fall much below the lower amount indicated.

These recommendations are presented, not as final, arbitrary standards, but as approximations, based on the older standards, on the data of recent experimental trials, and on the rations which have given excellent results in practice. It is hoped that in the present form they may be helpful until future investigations have thrown further light upon the nutrient requirements of the various classes of farm animals. Modified standards are not presented for growing dairy cattle, growing sheep, and growing pigs (breeding stock) on account of the lack of sufficient data.

	Digestible crude protein	Total digestible nutrients
1. *Dairy cows*	Lbs.	Lbs.
For maintenance of 1000-lb. cow	0.700	7.925
To allowance for maintenance add:		
For each lb. of 2.5 per ct. milk	0.045–0.053	0.256
For each lb. of 3.0 per ct. milk	0.047–0.057	0.286
For each lb. of 3.5 per ct. milk	0.049–0.061	0.316
For each lb. of 4.0 per ct. milk	0.054–0.065	0.346
For each lb. of 4.5 per ct. milk	0.057–0.069	0.376
For each lb. of 5.0 per ct. milk	0.060–0.073	0.402
For each lb. of 5.5 per ct. milk	0.064–0.077	0.428
For each lb. of 6.0 per ct. milk	0.067–0.081	0.454
For each lb. of 6.5 per ct. milk	0.072–0.085	0.482
For each lb. of 7.0 per ct. milk	0.074–0.089	0.505

The amount of dry matter to be fed daily per 1,000 lbs. live weight to dairy cows may range from 15.0 lbs. or even less with dry cows to 30.0 lbs. with cows yielding 2.0 lbs. of butter fat per head daily. Cows producing 1.0 lb. of fat per head daily should receive about 21.0 to 25.0 lbs. of dry matter daily per 1,000 lbs. live weight. The nutritive ratio may readily be found by computation; for example, a 1,200-lb. cow yielding daily 30.0 lbs. of 3.5 per ct. milk will require for maintenance and production 2.31 to 2.67 lbs. digestible crude protein and 18.99 lbs. total digestible nutrients. The nutritive ratio should hence not be wider than 1:6.1 to 1:7.2.

Live weight	Actual, per head daily			Per 1000 lbs. live weight			Nutritive ratio
	Dry matter	Digestible crude protein	Total digestible nutrients	Dry matter	Digestible crude protein	Total digestible nutrients	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1 :
2. Growing, fattening steers							
100 lbs.	1.41	0.32	1.66	14.1	3.2	16.6	4.2
150 lbs.	3.11	0.49	2.58	20.7	3.3	17.2	4.2
200 lbs.	4.81	0.67	3.48	24.0	3.4	17.4	4.1
250 lbs.	6.40	0.74	4.42	25.6	3.0	17.7	4.9
300 lbs.	8.00	0.80	5.36	26.7	2.7	17.9	5.6
350 lbs.	8.87	0.84	5.87	25.3	2.4	16.8	6.0
400 lbs.	9.72	0.87	6.32	24.3	2.2	15.8	6.2
450 lbs.	10.83	0.96	7.23	24.1	2.1	16.1	6.7
500 lbs.	11.95	1.04	7.88	23.9	2.1	15.8	6.5
550 lbs.	12.95	1.13	8.55	23.6	2.0	15.6	6.6
600 lbs.	13.94	1.22	9.25	23.2	2.0	15.4	6.7
700 lbs.	15.83	1.41	10.35	22.6	2.0	14.8	6.4
800 lbs.	17.13	1.61	11.43	21.4	2.0	14.3	6.2
900 lbs.	18.17	1.78	12.22	20.2	2.0	13.6	5.8
1000 lbs.	19.66	1.80	13.51	19.7	1.8	13.5	6.5
1100 lbs.	19.92	1.73	13.91	18.1	1.6	12.6	6.9
1200 lbs.	20.76	1.84	14.71	17.3	1.5	12.3	7.2

On comparing the foregoing standards for growing, fattening steers with the original Wolff-Lehmann standards for growing beef cattle, it will be seen that for the later stages of growth these standards are somewhat lower in dry matter and digestible nutrients. The standards here given for steers weighing 1,000 to 1,200 lbs. are markedly lower in dry matter and digestible nutrients than the original Wolff-Lehmann standards for fattening cattle. They are also lower than the following standards for fattening 2-yr.-old steers on full feed, which contemplate the feeding of all the concentrates the steers will eat. Tho cattle fed as indicated in the preceding standards will not make maximum gains, the gains are produced with a smaller amount of feed than if a heavier ration were fed. For example, 1,000-lb. steers fed by Haecker according to this system until they reached a weight of 1,200 lbs. required only 8.0 lbs. of total digestible nutrients per pound of gain.

Animal	Per day per 1,000 lbs. live weight			Nutritive ratio
	Dry matter	Digestible crude protein	Total digestible nutrients	
	Lbs.	Lbs.	Lbs.	1:
3. Fattening 2-yr.-old steers on full feed				
First 50–60 days	22.0–25.0	2.0–2.3	18.0–20.0	7.0– 7.8
Second 50–60 days	21.0–24.0	1.9–2.3	17.0–19.5	7.0– 7.8
Third 50–60 days	18.0–22.0	1.8–2.1	16.0–18.5	7.0– 7.8
4. Ox at rest in stall	13.0–21.0	0.6–0.8	8.4–10.4	10.0–16.0
5. Wintering beef cows in calf	14.0–25.0	0.7–0.9	9.0–12.0	10.0–15.0
6. Horses				
Idle	13.0–18.0	0.8–1.0	7.0– 9.0	8.0–9.0
At light work	15.0–22.0	1.1–1.4	10.0–13.1	8.0–8.5
At medium work	16.0–24.0	1.4–1.7	12.8–15.6	7.8–8.3
At heavy work	18.0–26.0	2.0–2.2	15.9–19.5	7.0–8.0
7. Brood mares suckling foals, but not at work	15.0–22.0	1.2–1.5	9.0–12.0	6.5–7.5
8. Growing colts, over 6 months	18.0–22.0	1.6–1.8	11.0–13.0	6.0–7.0
9. Fattening lambs				
Weight 50–70 lbs.	27.0–30.0	3.1–3.3	19.0–22.0	5.0–6.0
Weight 70–90 lbs.	28.0–31.0	2.5–2.8	20.0–23.0	6.7–7.2
Weight 90–110 lbs.	27.0–31.0	2.3–2.5	19.0–23.0	7.0–8.0
10. Sheep, maintaining mature				
Coarse wool	18.0–23.0	1.1–1.3	11.0–13.0	8.0–9.1
Fine wool	20.0–26.0	1.4–1.6	12.0–14.0	7.5–8.5
11. Breeding ewes, with lambs	23.0–27.0	2.6–2.9	18.0–20.0	5.6–6.5
12. Growing, fattening pigs				
Weight 30–50 lbs.	46.2–51.0	7.8–8.5	41.0–45.4	4.0–4.5
Weight 50–100 lbs.	37.0–40.8	5.5–6.0	32.9–36.4	5.0–5.6
Weight 100–150 lbs.	32.4–35.8	4.4–4.9	28.8–31.9	5.5–6.2
Weight 150–200 lbs.	29.0–32.0	3.5–3.9	25.8–28.5	6.2–7.0
Weight 200–250 lbs.	25.5–28.1	3.0–3.4	22.7–25.0	6.5–7.3
Weight 250–300 lbs.	22.4–24.8	2.6–2.9	20.0–22.0	6.7–7.5
13. Brood sows, with pigs	20.0–24.0	2.4–2.7	18.0–21.0	6.0–7.0

Table VI. Mineral Matter in 1,000 Lbs. of Representative Feeding Stuffs

The data presented in the following table have been compiled from analyses by the American Experiment Stations, especially the analyses reported by Forbes in *Ohio Bulletin 255,* supplemented by others from German sources.

Feeding stuff	Potash K O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Sulphuric acid SO_3	Phosphoric acid P_2O_5	Silica SiO_2	Chlorin Cl
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Corn	4.0	0.4	0.2	1.8	0.11	3.8	6.9	0.3	0.65
Gluten feed	2.3	5.7	3.5	3.6	....	14.6	6.2	....	0.90
Wheat	5.3	1.6	0.6	2.2	0.23	5.4	8.6	0.4	0.82
Wheat flour	1.0	1.5	0.3	0.3	....	3.6	2.0	....	0.70
Red dog flour	7.6	...	1.7	4.8	....	6.5	20.0	....	1.40
Standard wheat middlings	11.8	1.4	0.8	5.4	....	5.8	21.1	....	....
Wheat bran	16.2	2.4	0.9	7.3	0.34	6.7	29.5	0.3	0.90
Oats	5.6	2.3	1.4	2.0	0.38	4.9	8.1	12.5	0.70
Malt sprouts	18.3	1.1	2.1	3.0	0.95	20.0	16.5	13.5	3.60
Brewers' grains, dried	0.9	3.5	2.2	2.6	0.39	9.7	9.9	12.3	0.58
Rough rice	2.6	1.0	0.2	1.2	0.31	....	4.9	41.6	0.02
Polished rice	0.6	0.4	0.1	0.4	....	2.6	1.7	....	0.36
Rice polish	11.7	1.5	0.4	10.9	....	4.2	30.8	....	1.34
Kafir grain	3.1	0.8	0.2	2.1	....	4.1	5.7	....	1.04
Cottonseed meal	18.1	3.5	3.6	8.6	0.84	12.4	26.7	5.5	0.39
Linseed meal, old process	12.7	3.4	5.1	8.1	1.44	10.2	17.0	6.9	0.86
Bean, navy	13.7	1.0	2.8	2.9	....	4.8	7.8	....	0.40
Cowpea	14.9	2.2	1.4	3.4	....	6.0	10.1	....	0.40
Soybean	24.7	6.1	2.9	3.8	....	10.3	13.7	....	0.28
Skim milk	1.7	0.6	1.8	0.2	....	0.8	2.2	....	0.91
Whey	2.6	0.4	0.6	0.1	....	0.2	1.2	....	1.18
Beet pulp, dried	3.8	2.2	9.2	4.2	....	3.1	2.4	9.0	0.43
Distillers' grains, dried, from corn	1.7	1.9	0.6	0.8	....	11.7	6.8	....	0.60
Corn stover	12.9	6.5	6.6	1.4	0.71	4.3	4.5	9.1	2.87
Sorghum fodder	25.3	...	3.9	2.9	0.79	....	2.3	5.9	5.60
Bluegrass hay	21.0	1.7	4.3	3.6	....	7.7	5.4	....	2.15
Timothy hay	13.6	4.3	2.5	1.7	0.37	3.7	3.1	14.2	1.83
Alfalfa hay	22.3	5.6	19.5	5.9	1.68	7.8	5.4	8.1	4.74
Red clover hay	16.3	1.2	16.0	4.5	0.67	4.4	3.9	1.7	2.39
Cowpea hay	41.3	2.5	25.4	16.2	....	7.9	9.6	....	1.49
Soybean hay	23.3	1.8	17.2	10.3	....	5.8	6.8	....	0.75
Wheat straw	7.4	3.0	2.9	1.0	0.26	3.8	1.3	28.4	1.98
Mangel	2.2	1.1	0.2	0.7	0.08	0.6	0.4	0.2	1.58

Table VII. Weight of Various Concentrates

In computing rations for farm animals it is desirable to know the weight per quart, or the bulk, of the different concentrates. The following table, compiled from *Massachusetts Bulletin 136* by Smith and Perkins, *Louisiana Bulletin 114* by Halligan, and *Indiana Bulletin 141* by Jones, Haworth, Cutler, and Summers is therefore presented.

Feeding stuff	One quart weighs	One pound measures	Feeding stuff	One quart weighs	One pound measures
	Lbs.	Qts.		Lbs.	Qts.
Whole corn	1.7	0.6	Brewers' grains, dried	0.6	1.7
Corn meal	1.5	0.7	Millet, foxtail	1.6	0.6
Corn-and-cob meal	1.4	0.7	Rice polish	1.2	0.8
Hominy feed	1.1	0.9	Rice bran	0.8	1.3
Gluten feed	1.3	0.8	Buckwheat	1.4	0.7
Gluten meal	1.7	0.6	Buckwheat flour	1.6	0.6
Germ oil meal	1.4	0.7	Buckwheat middlings	0.9	1.1
Corn bran	0.5	2.0	Buckwheat bran	0.6	1.7
Wheat	1.9	0.5	Buckwheat hulls	0.5	2.0
Wheat, ground	1.7	0.6	Cotton seed	0.8	1.3
Flour wheat middlings	1.2	0.8	Cottonseed meal	1.5	0.7
Standard wheat middlings	0.8	1.3	Cottonseed hulls	0.3	3.3
Wheat bran	0.5	2.0	Flaxseed	1.6	0.6
Wheat feed (shorts and bran)	0.6	1.7	Linseed meal, old process	1.1	0.9
Wheat screenings	1.0	1.0	Linseed meal, new process	0.9	1.1
Rye	1.7	0.6	Flax feed	0.8	1.3
Rye meal	1.5	0.7	Flax screenings	1.1	0.9
Rye middlings	1.6	0.6	Beans, navy	1.7	0.6
Rye bran	0.8	1.3	Cowpeas	1.7	0.6
Rye feed (shorts and bran)	1.3	0.8	Peas, field	2.1	0.5
Oats	1.0	1.0	Soybeans	1.8	0.6
Oatmeal	1.7	0.6	Cocoanut meal	1.5	0.7
Oats ground	0.7	1.4	Cocoanut cake	1.3	0.8
Oat feed	0.8	1.3	Sunflower seed	1.5	0.7
Oat middlings	1.5	0.7	Beet pulp, dried	0.6	1.7
Oat hulls	0.4	2.5	Distillers' grains, dried	0.6	1.7
Barley	1.5	0.7	Molasses, cane, or blackstrap	3.0	0.3
Barley meal	1.1	0.9	Molasses feed	0.8	1.3
Malt sprouts	0.6	1.7	Alfalfa meal	0.6	1.7

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